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UNIVERSITY OF ALBERTA
CERTAIN LIMNOLOGICAL CHARACTERISTICS
OF THE LA BICHE AND WANDERING RIVERS

by

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A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
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FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled Certain Limnological Characteristics of the La Biche and Wandering Rivers, submitted by Michael Ross Robertson in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The La Biche River and one of its tributaries, the Wandering River, were investigated during the period May 1965 to May 1967. Physical and chemical characteristics of the two rivers were found to be quite different. Wandering River has a muskeg origin and is modified by a small eutrophic lake, Lyle Lake. Extensive winter stagnation in Lyle Lake influences the environment of Wandering River in winter and markedly affects its fauna by eliminating several of the bottom invertebrates. The La Biche River is more uniform throughout its length, being very little influenced by Lac la Biche, which does not exhibit winter stagnation. In La Biche River environmental conditions for aquatic life are favorable throughout the year.

Life cycles of major macrobenthic invertebrates were investigated using the population-histogram technique. Tricorythodes minutus, Caenis simulans, Taeniopteryx nivalis, Neureclipsis bimaculatus, Hydropsyche recurvata, and Cheumatopsyche sp. were annual and univoltine. Baetis sp. appeared to be annual and bivoltine. Seasonal changes of benthic animals were found to be different in the two rivers. There were more plankters draining into the Wandering River from Lyle Lake than draining into the La Biche River from Lac la Biche. It is suggested that this accounts for the larger number of net-feeding hydropsychids of Wandering River. The drift fauna in the Wandering River indicated spatial differences between stations; drift below Lyle Lake showed variations in composition throughout a 24 hour period.

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Mr. D. Rosenberg identified the Corixidae; Dr. G. F. Edmunds, Jr. identified certain of the adult Ephemeroptera; Dr. R. O. Brinkhurst identified the Oligochaeta; and A. Nimmo identified certain of the adult Trichoptera. To these people I express my sincere thanks.

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INTRODUCTION

The northern regions of Canada contain large numbers of streams that are closely associated with lakes. One has only to examine a map of northern Alberta to appreciate the areal importance of these lake-stream systems. There are few, if any, major watersheds in northern Alberta that are without an interconnected system of lakes and streams; the lake-stream systems extend across all of northern Canada. The climate of these northern regions is one of very long and extremely cold winters resulting in long periods of ice cover on most streams and lakes. Access is poor, especially in spring and winter; consequently the lake-stream systems generally have been by-passed by limnological investigators. The unusual physical characteristics of the rivers do, however, present unique types of habitat for aquatic life. Little is known about the limnology of northern streams during the long winter, or in what ways the associated lakes might influence these streams.

Since most studies of lotic environments have covered only the summer period, when access is easy and methods are not laborious, information about yearly changes in river faunas is quite scarce. Often the quantitative aspects of stream biology are stressed without an understanding of the seasonal changes. Since most macrobenthic invertebrates of streams are insects having a definite seasonal distribution in numbers, size, and space, the summer approach can yield only a limited amount of information on the nature of a stream community.

As the northern regions of Canada are developed, we can expect that the lake-stream systems of these regions will be altered in one way or another by man. Many of these alterations may be detrimental to aquatic life, e.g. introduction of domestic and industrial wastes, insecticide

treatments, and erosion. It is important that these water systems be analysed prior to any alterations, so that the effect of the various interference agents might be determined. It is equally important that we have the proper perspective of these streams in regard to other running water systems, and ultimately that we be able to classify them in the lotic systems spectrum.

This study was carried out on two rivers, La Biche River and Wandering River, in an effort to determine the seasonal changes of aquatic invertebrate fauna, the nature of the macrobenthic invertebrate life cycles, and the changes in the physics and chemistry of the river water both under its own ice cover and downstream from an ice covered lake.

DESCRIPTION OF STUDY AREA

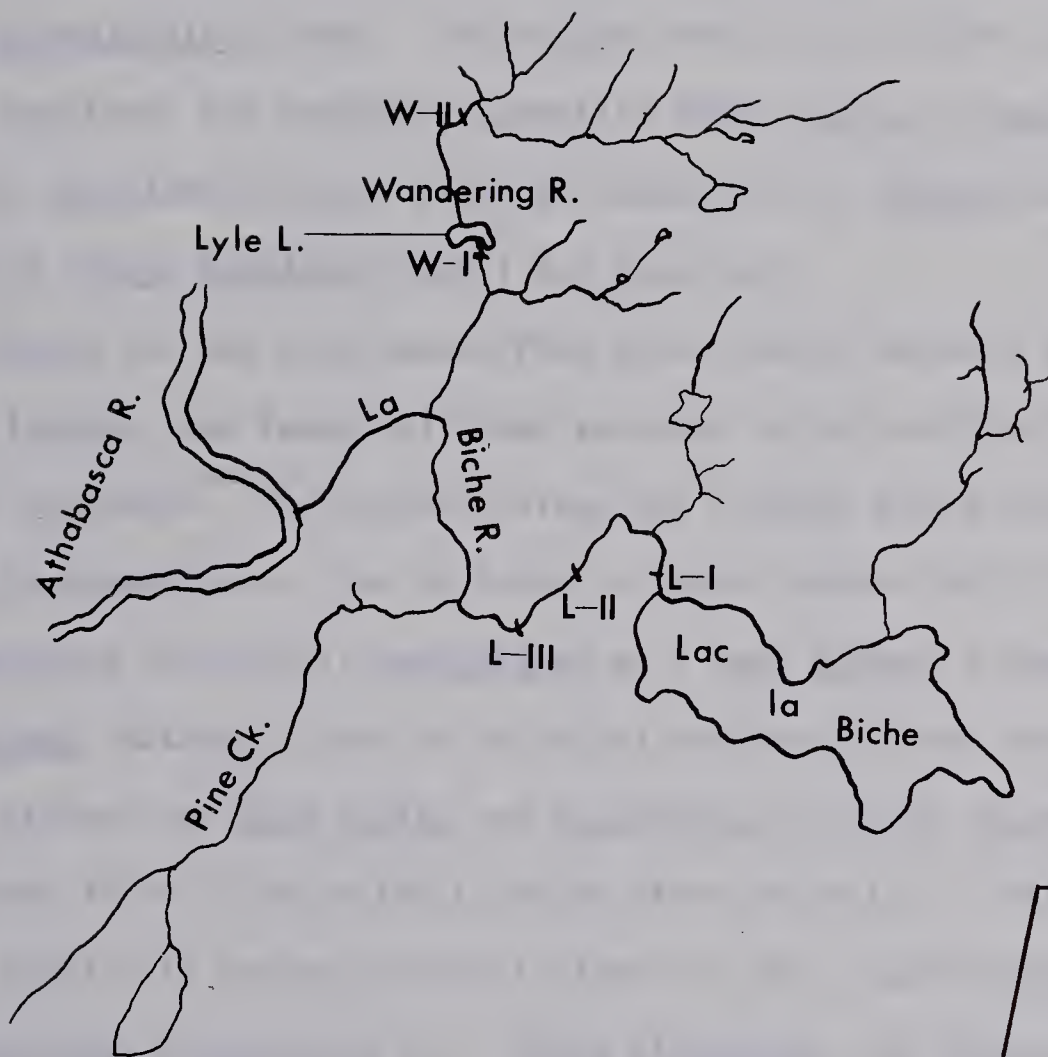
The La Biche River system (Fig. 1), flowing in the region ca. 240 km northeast of Edmonton, Alberta, lies between Lac la Biche on the east and the Athabasca River on the west. The most northward branch is Wandering River, originating north of Lyle Lake. Pine Creek drains the most southward area of the La Biche River system.

The topography of the region is rolling, and most parts are well drained. The larger lakes of the region are the result of the Wisconsin Glaciation, which receded about 11,500 years ago. The generally northwest to southeast orientation of the lakes is indicative of the direction in which glaciation receded. The La Biche River, therefore, probably attained its present day drainage pattern about 11,500 years ago. Fluctuation in lake levels, formation of ox-bows, etc., may have modified the original pattern.

Wynnyk et al. (1956) describe the area as having primarily Grey-Wooded soils, originating from glacial till, lacustrine clays, and peat bogs. Because of bogs, the northern region of the La Biche system is of poor agricultural quality; agricultural conditions improve in the southern part of the La Biche watershed, and mixed farming is common in the Pine Creek region.

The average frost-free period of the region is 111 days (Wynnyk et al., 1956), and the mean annual temperature and precipitation are 1.45° C and 43.9 cm respectively (Lindsay, Pawluk and Odymsky, 1962). The northern latitude of the La Biche region (54°) and its remoteness from the ocean (1500 km) result in extremely cold winters and warm summers, with maximum precipitation from June to September. Water bodies generally have a considerable ice covering during the greater part of the winter,

Figure 1. Map of the study area. L-I, L-II, L-III, W-I and W-II are the sampling stations used during the study.



19km



KEY MAP

usually from November to May. Table I summarizes important meteorological features at Lac la Biche Airport for the study period, May 1965 to May 1967.

The northern part of the study area lies at the edge of the Canadian taiga, or boreal forest. Here, the dominant vegetation is white spruce, Picea glauca (Moench) Voss, interspersed with the typical bog flora of black spruce, Picea mariana (Mill.) BSP.; Sphagnum sp.; and Labrador-tea, Ledum groenlandicum Oeder. The region south of Lyle Lake lies in the aspen parkland, the dominant vegetation being Populus tremuloides Michx. and its associated shrubs, although locally birch (Betula spp.) and jackpine (Pinus banksiana Lamb.) are important.

Except for the area around Pine Creek, which has been modified for mixed farming, the impact of human activity on the La Biche River system is not extensive. The northern areas are trapped during winter, and some stock is grazed here. Lac la Biche is fished commercially for Coregonus clupeaformis (Mitchill), Leucichthys sp., Esox lucius, Linnaeus, and Perca flavescens (Mitchill); the La Biche and Wandering Rivers support a modest sport fishery for Esox lucius and Stizostedion vitreum vitreum (Mitchill). The first 10 to 15 km of the La Biche River below Lac la Biche have a fish fauna (Table II) derived primarily from the lake, namely Coregonus clupeaformis, Leucichthys sp., Perca flavescens, and Notropis hudsonius (Clinton). The lower reaches have a more typical riverine fauna of Percopsis omiscomaycus (Walbaum), Catostomus spp., Coregonus williamsonii (Girard) and Hiodon alosoides (Rafinesque). The Wandering River has a few species not present in the La Biche, such as Rhinichthys cataractae (Valenciennes), Cottus ricei (Nelson), and Thymallus arcticus (Pattas), but otherwise has a fish fauna similar to the lower reaches of the La Biche River.

Table I: Air temperatures and precipitation at Lac la Biche Airport from May 1965 to May 1967. The letter s indicates snow.

<u>Month</u>	<u>Air Temperature (°F)</u>			<u>Total Monthly Precipitation (inches)</u>
	<u>Mean</u>	<u>Max.</u>	<u>Min.</u>	
1965 May	47.8	73	23	2.69
June	55.9	82	31	4.32
July	60.7	87	41	2.22
August	56.0	84	36	4.17
September	40.2	71	17	1.05
October	44.1	71	23	0.25
November	14.4	54	-22	0.89 s
December	8.3	44	-40	0.58 s
1966 January	-16.3	24	-55	1.36 s
February	6.2	46	-32	0.21 s
April	32.0	58	0	0.85 s
May	51.4	82	29	2.33
June	54.2	82	31	1.29
July	60.5	85	41	2.08
August	57.3	84	34	5.57
September	52.4	79	31	0.43
October	38.4	76	10	0.27
November	9.1	45	-21	0.91 s
December	10.0	44	-32	1.14 s
1967 January	- 1.0	41	-45	0.79 s
February	5.8	45	-36	1.89 s
March	10.2	39	-30	1.85 s
April	29.4	59	- 6	0.90 s
May	48.4	84	19	0.01

Since the study necessitated sampling close to a road that could be travelled in all weather, sampling stations were selected on the basis of access. Initially three stations, L-I, L-II and L-III, were established on the La Biche River; and two stations, W-I and W-II, established on the Wandering River (Fig. 1). However the seasonal studies, both biological and chemical, were restricted to a single station on each stream, L-II (Fig. 2) and W-I (Fig. 3).

Table III shows the substrate features of all stations and their location in respect to the associated lakes. Station L-I, located about 1.6 km downstream from Lac la Biche, has a rich, organic mud-bottom with extensive growths of Typha latifolia L. and Scirpus validus Vahl along its edges. Downstream from L-I, the river drops markedly (Fig. 4), becomes shallower and has a rubble-sand substrate supporting growths of Potamogeton. Station L-II exhibits features of this region of the river. Station L-III is at the lower end of the rubble-sand stretch and, because of the slower current here, has a substrate containing more silt. Downstream from L-III, and continuing to its confluence with the Athabasca River, the La Biche River narrows, and the bottom, except at infrequently encountered riffle areas, becomes almost entirely composed of silt. In this region, beds of Myriophyllum exalbescens Fern, Potamogeton spp., and occasionally Sagittaria cuneata Sheld occur in bends and backwaters.

Station W-I on the Wandering River is located 2 km below Lyle Lake in a fast moving, shallow riffle region. Because of the steep gradient in this reach (Fig. 5), the riffle did not completely freeze over in winter. This was the only station of either river to remain open in winter. Station W-II, located 15 km above Lyle Lake, is narrow, deep and has a mud bottom.

Table II: Fishes of the La Biche and Wandering Rivers. The letter X indicates species present.

<u>Species</u>	<u>La Biche River</u>	<u>Wandering River</u>
<u>Coregonus clupeaformis</u> (Mitchill)	X	
<u>Leucichthys</u> sp.	X	
<u>Catostomus commersonii</u> (Lacepede)	X	X
<u>Catostomus catostomus</u> (Forster)	X	X
<u>Perca flavescens</u> (Mitchill)	X	
<u>Stizostedion v. vitreum</u> (Mitchill)	X	X
<u>Notropis hudsonius</u> (Clinton)	X	
<u>Lota lota</u> (Walbaum)	X	X
<u>Esox lucius</u> Linnaeus	X	X
<u>Hybopsis plumbea</u> (Agassiz)	X	X
<u>Coregonus williamsonii</u> (Girard)	X	
<u>Hiodon alosoides</u> (Rafinesque)	X	
<u>Thymallus arcticus</u> (Pattas)		X
<u>Rhinichthys cataractae</u> (Valenciennes)		X
<u>Cottus ricei</u> (Nelson)		X
<u>Eucalia inconstans</u> (Kirtland)		X
<u>Percopsis omiscomaycus</u> (Walbaum)	X	X

Figure 2. Station L-II of La Biche River, summer of 1966 and winter of 1966-1967.



Figure 3. Station W-I of Wandering River, summer of 1966 and winter of 1966-1967.



Table III: Sampling stations of the La Biche and Wandering Rivers.

<u>La Biche River</u>		
<u>Station</u>	<u>Distance from Lac la Biche</u>	<u>Substrate</u>
L-I	1.6 km	mud-bottom; deep pool
L-II	12.9 km	rubble-sand; shallow riffle
L-III	19.3 km	rubble-mud; deep pool
<u>Wandering River</u>		
<u>Station</u>	<u>Distance from Lyle Lake</u>	<u>Substrate</u>
W-I	2.0 km downstream	boulder-rubble-sand; shallow riffle
W-II	15.3 km upstream	mud-bottom; deep pool

Figure 4. Longitudinal profile of the La Biche River. The cross sectional profiles of the sampling stations are shown below their respective locations.

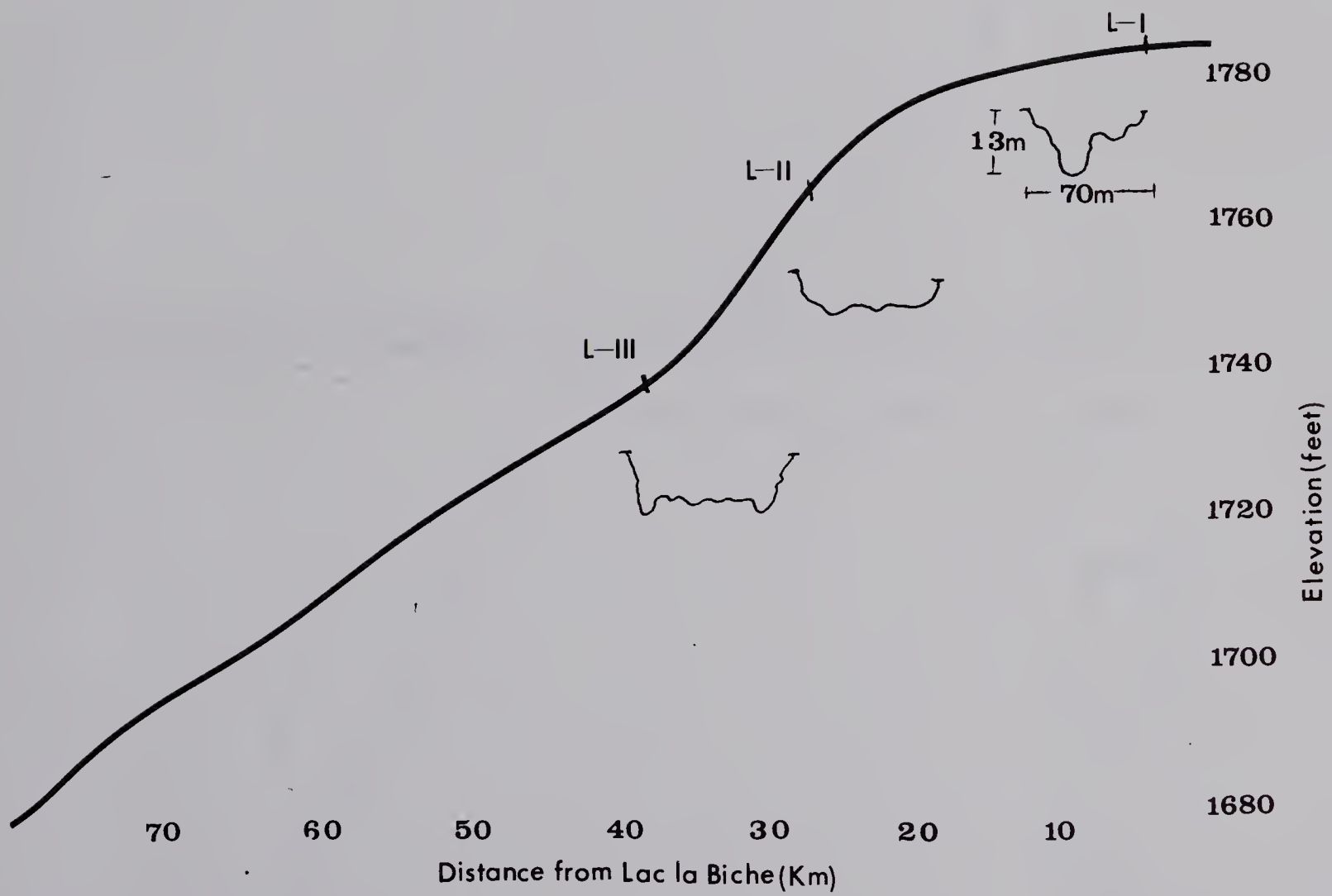
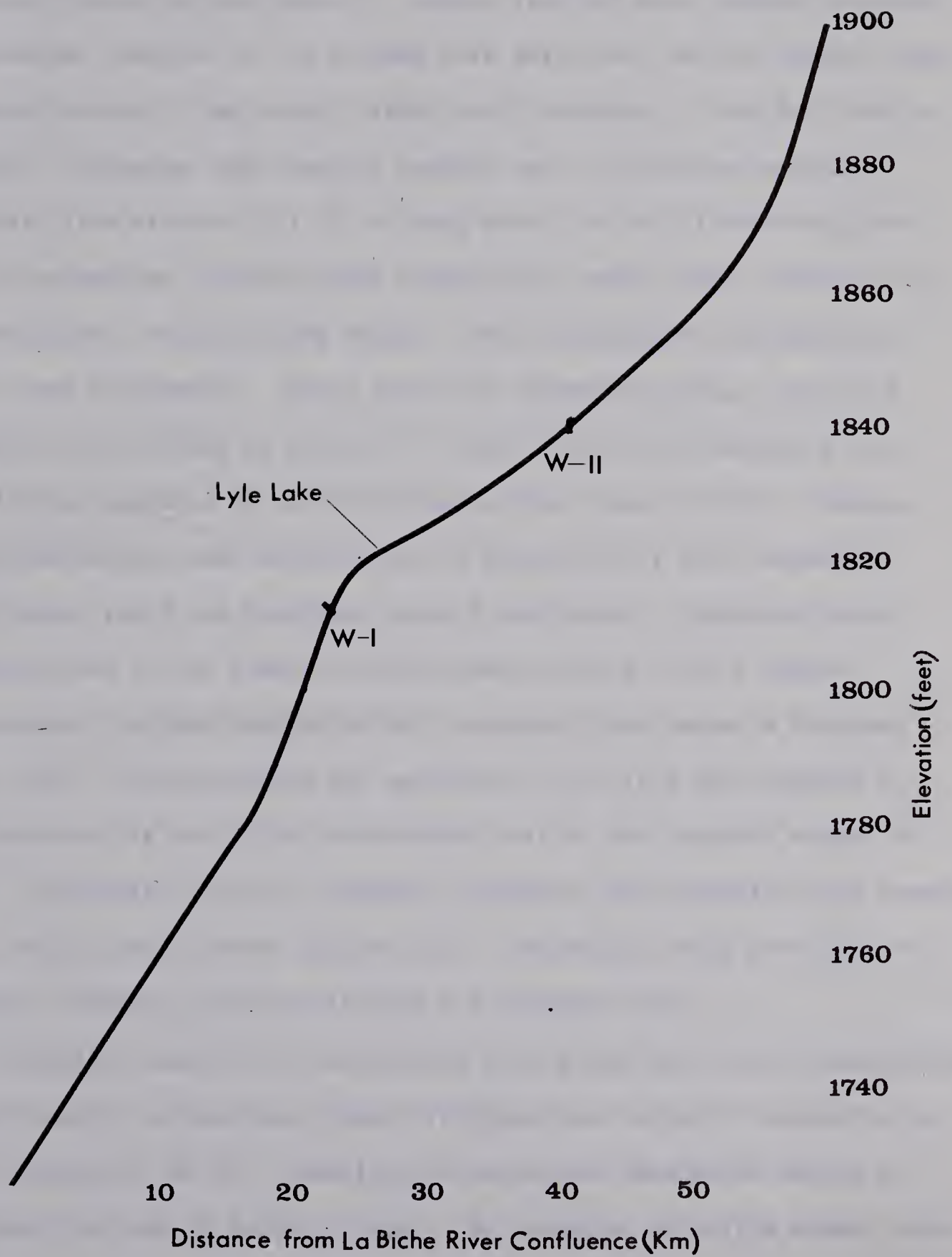


Figure 5. Longitudinal profile of the Wandering River, estimated from topographic maps.



METHODS

During the period May to September 1965, work on La Biche and Wandering Rivers was exploratory. Access stations were located, physical and chemical features of the streams were described, and the general types and distribution of the aquatic fauna were determined. From May 1966 to May 1967, biological and chemical samples were collected at monthly intervals from station L-II of La Biche River and W-I of Wandering River. Field observations included water temperature, water level, hydrogen ion concentrations, and dissolved oxygen. Water temperature was measured with a hand thermometer. Water level was determined using a yardstick attached to the bridge at station W-I, with flow of the Wandering River at W-I being measured by the cork-float method (Welch, 1948). Hydrogen ion concentrations were measured with a Hellige color disk comparator using Cresol-red-B and Bromthymol-blue-D indicators. Dissolved oxygen was determined by the standard Winkler method using 0.025 N sodium thiosulphate; percent saturation was calculated from Rawson's Nomogram (Reid, 1961). Water samples not analysed in the field were removed to the laboratory in one-litre polyethylene bottles and analysed within 24 hours. Alkalinity, silica, phosphate, sulphate, and turbidity were measured with a Hach portable water analysis kit. Occasional tests were made for chloride, hardness, nitrite nitrogen and apparent color.

Biological samples for determining life cycles and percent compositions of macrobenthic animals were taken with a pond net having 10 meshes/cm and a net opening of 988 cm². Sampling procedure was determined mainly by substrate type and by depth of water. For example, in riffle areas, rocks were turned over and cleaned in front of the net; in slower reaches, disrupting the upper few centimetres of mud and gravel with the hoop of the

net, brushing aquatic plants, etc. proved satisfactory. Sampling was continued until it was judged that an adequate sample was obtained. Hence rather than a delimited sample of bottom being taken, the above method has the advantage of obtaining an extensive sample of the entire stream bed. This method also could be carried out at station W-I during the winter, as the river never completely froze over here. At station L-II, however, during the ice-cover period, the net was held on the downstream side of a hole in the ice, while the region upstream was disrupted with a metal probe. The entire region accessible through the hole was sampled in this way.

Samples were fixed in ten percent formalin and returned to the laboratory where they were washed with tap water. The organisms were "floated" with a saturated sucrose solution, picked out of the solution, and stored in 95% ethyl alcohol. Flotation greatly facilitated the removal of smaller organisms from the sample. The organisms were then sorted into various taxonomic groups.

Identification of macrobenthic animals, especially immature aquatic insects, was a major problem in this study. This mainly is due to species identification of aquatic insects being based on adult characteristics. If available taxonomic keys proved unsatisfactory for completing the binomial of the immature stage, certain morphological features were described for the species in question, and the species designated by letter or number, until the correct adult could be associated with the immature form. Organisms encountered infrequently, e.g. coleopterans, many dipteran groups, were separated only to order or family. The various taxa were then counted, and the frequently-occurring organisms measured to the nearest millimetre.

PHYSICAL AND CHEMICAL CHARACTERISTICS

Water Level

The Wandering River reached maximum stages in September 1966 and again in May 1967 (Fig. 6). At the latter time, it had a flow of 850 c.f.s., due mainly to melting snow in the drainage area. This river also fluctuates noticeably after heavy summer rains, whereas the La Biche River does not. In May 1966 Wandering River flooded in several areas above Lyle Lake. The most recent flood on the La Biche River was recorded in 1958. Water level of Wandering River dropped markedly during late autumn to a minimal stage in late winter, and, although water level readings were not taken, the same phenomenon was observed in the La Biche River.

Temperature

The seasonal temperature cycles of the two rivers were similar (Fig. 6). Maximum water temperatures were near 20.0° C during July 1966, fairly high values considering the northern location of these streams. Temperatures dropped rapidly in the autumn, reaching winter values near 0° C during November. Ice began to form at L-II during the first week of November 1966 and by 19 November had reached a depth of 25 cm. Station W-I did not completely freeze over, but formed an ice-snow cover similar to that described by Kamler (1965) for Polish mountain streams. Ice became progressively thicker at L-II, and on 27 March 1967 it was over one metre thick and was covered by an equally thick layer of snow. Snow depth on the ice varied, but never was observed to be less than 0.3 metres. Ice started breaking up in both rivers by early April 1967, and by mid-April the rivers were ice-free. Immediately following the passage of ice, the rivers warmed rapidly and by May 1967 had attained "summer temperatures". In brief, the

seasonal pattern consists of long periods of "summer" and "winter" temperatures, with rapid cooling and warming in autumn and spring.

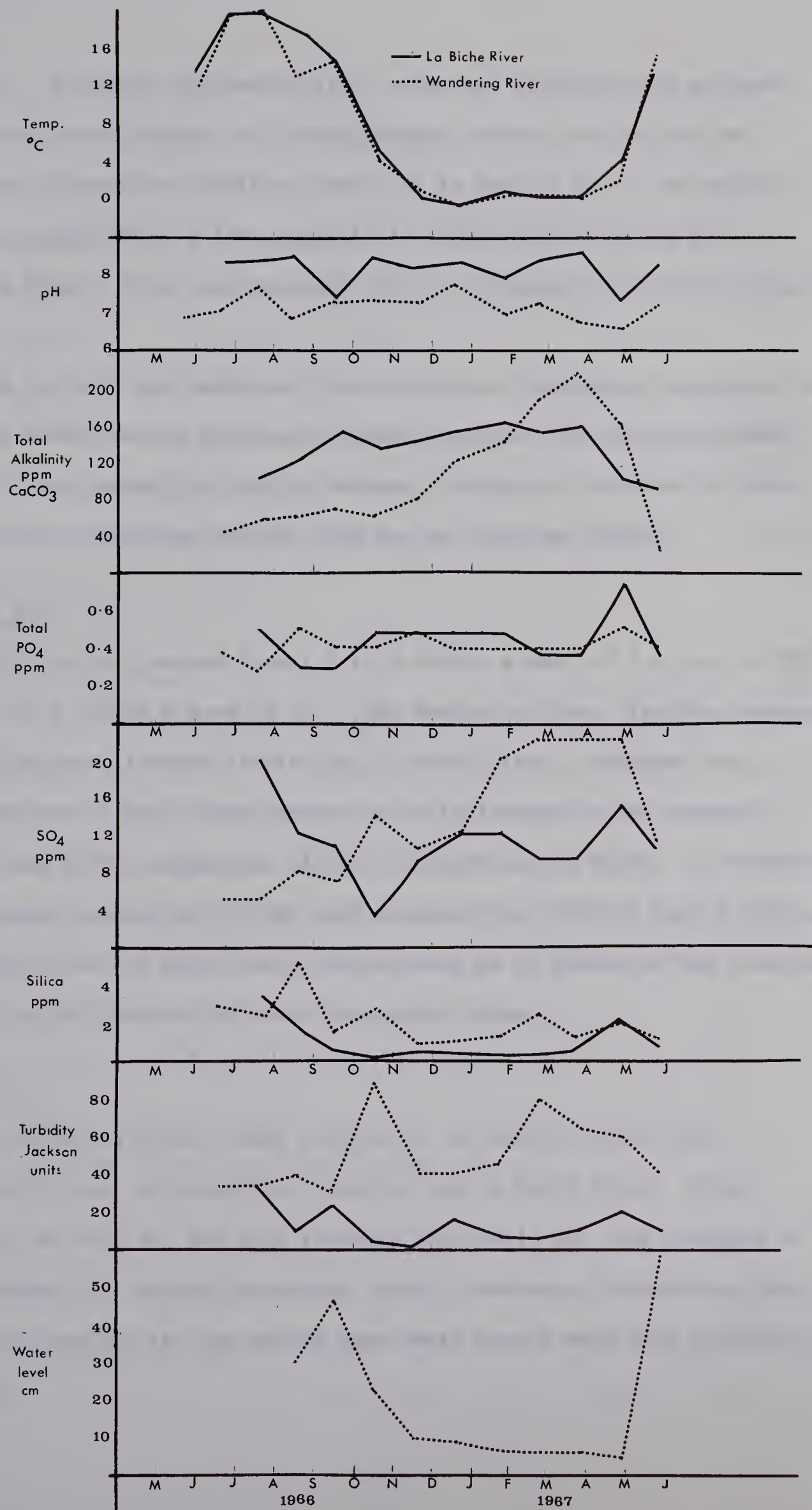
Mean temperatures at L-II and W-I were 10.4°C and 9.5°C respectively. Water temperatures were above 10°C for 18 weeks and below 5°C for 22 weeks. This is different from that found by Hartland-Rowe (1964) for a mountain stream in Alberta where the water temperatures were above 10°C for only seven weeks of the year and below 5°C for 39 weeks. Macan (1958), studying a stream in England, found periods of 24 weeks above 10°C and 12 weeks below 5°C . Regarding these calculated temperature parameters, La Biche and Wandering Rivers resemble more closely Macan's English stream than Hartland-Rowe's mountain stream, although the latter is located only 800 km south of the La Biche watershed. The North Saskatchewan River, rising in the mountains and flowing some 240 km across the central Alberta plain, had about 12 weeks of water temperature above 10°C and 25 weeks below 5°C (Paterson, 1966). These values would place it between Hartland-Rowe's mountain stream and the La Biche and Wandering Rivers.

Turbidity

Turbidity at W-I was consistently higher than at L-II. La Biche River exhibited generally low turbidities, which, except for an unexplained increase in December, followed the seasonal flow pattern. In autumn this river was very clear, resembling a mountain brook or spring.

Construction of the McMurray Highway may have contributed to the consistently higher turbidities of Wandering River. Turbidity of this river did not correlate with flow, and this is due, in part, to the muskeg origin of Wandering River. The dark color of muskeg streams, due to dissolved organic matter, increases as flow decreases, a phenomenon opposite that of

Figure 6. Selected physical and chemical characteristics at
L-II and W-I, June 1966 to May 1967.



turbidity. Although, photometrically, color and turbidity are analysed at different wave lengths, all interferences between the two are not eliminated. Hence the turbidity level can in part be due to an entirely different constituent, color, and this is likely the situation in Wandering River. Color was measured only at infrequent intervals in this study.

Both La Biche and Wandering Rivers exhibited unexpected increases in turbidity under the ice (although W-I was ice-free, the region upstream was not). The reason for this is unknown. Perhaps an increase in color due to winter stagnation in Lyle Lake was an important factor.

Hydrogen Ion

The pH at L-II varied from 7.2 to 8.6 with a mean of 7.9, and at W-I from 6.5 to 7.7 with a mean of 7.1. The Wandering River, draining numerous sphagnum regions, is more acidic than La Biche River. Hydrogen ion concentrations in both rivers appear to be influenced by the seasonal turnover and winter conditions of Lyle Lake and Lac la Biche. In Wandering River, winter stagnation in Lyle Lake accounts for lower pH values during late winter, and for both rivers the increase in pH values of May coincides with the spring turnover of their respective lakes.

Alkalinity

The Wandering River, again reflecting its muskeg origin, was consistently lower in alkalinity than was the La Biche River. Total alkalinity at both W-I and L-II followed conversely the flow patterns in these rivers, i.e. during the spring runoff, when water levels were high, alkalinity was low; in late winter when water levels were low, alkalinity was high.

Phosphate

Total phosphate levels were rather high in both rivers considering the unpolluted nature of this river system. Hayes and Anthony (1958), Ball and Hooper (1963) and Clifford (1966) recorded substantially lower values for unpolluted streams in other regions of North America. Phosphate levels were fairly constant, and, instead of being correlated with flow, they appeared more dependent on lake conditions. For example, autumnal decreases at L-II coincided with a plankton bloom in Lac la Biche (personal communication: M. E. Pinsent, University of Alberta). The large increase in the La Biche River during the spring melt is unexplained; it is possibly due to a contaminated sample.

Sulphate

For most of the study period, sulphate content of La Biche River was markedly different from that of Wandering River. Both rivers underwent fluctuations in sulphate concentration that were apparently unrelated to flow. The gradual increase of sulphate throughout the winter at W-I can be explained by the winter stagnation that occurred in Lyle Lake. When winter stagnation is intense, anaerobic conditions ensue, and bacterial action results in the production of hydrogen sulphide gas. This gas presumably drained from Lyle Lake into Wandering River and during its passage downstream was exposed to oxygen and converted to sulphate, especially at the ice-free, turbulent riffle at W-I.

Silica

Silica concentrations, measured as silica oxide, were consistently larger, and fluctuations more frequent at W-I than at L-II. Since little is known about the role of silica in water, one can only speculate about this

mineral in La Biche and Wandering Rivers. Müller-Haeckel (1965) observed that an increase in diatom numbers for a German stream coincided with a downstream decrease in silica oxide. Such a phenomenon could account for the silica variations between Wandering and La Biche Rivers; but as constant records of diatom numbers were not kept, it is not known if this might be the case.

Nitrogen, Chloride and Color

Nitrate levels were 0.3 ppm at L-I and L-III (24 August 1966) and 2.8 and 1.6 ppm at W-I (18 August and 8 September 1965, respectively). Chloride concentrations in the La Biche River varied from 5 ppm (L-III, 15 September 1966) to less than 0.5 ppm (L-II, 15 September 1966). Wandering River was usually lower in chloride, varying from 2.5 ppm (W-II, 20 July 1966) to a trace at W-I on the same date. During April and May 1967 apparent color at W-I (290 and 140 ppm) was considerably higher than at L-II (90 and 50 ppm).

Dissolved Oxygen

In La Biche River, dissolved oxygen levels were relatively high in all seasons (Table IV). The lowest value observed was 8.4 ppm on 25 May 1967. During winter, oxygen content was found never to be below 65% saturation, remaining near this level or slightly higher during the entire period of ice cover.

In Wandering River, oxygen conditions were quite different, particularly during the winter. In summer 1966, dissolved oxygen at the W-I riffle was near 100% saturation. However dissolved oxygen content started dropping during the winter, and by April 1967 the water contained only 0.5 ppm, even after flowing across 350 metres of the open riffle. The low oxygen content is accounted for by winter stagnation in Lyle Lake. There was even an odor.

Table IV: Dissolved oxygen determinations at L-II and W-I, 1966-1967.

<u>Date</u>	<u>Time</u>	<u>Water Temperature C°</u>	<u>O₂ ppm</u>	<u>O₂ percent saturation</u>
L-II				
1966 20 July	1030	19.0	9.0	95
24 August	1355	17.0	8.9	90
15 September	1350	14.5	9.1	90
16 October	1100	5.0	11.2	87
19 November	0900	0.0	9.6	65
20 December	0900	- 1.0	10.2	70
1967 26 February	1115	0.0	9.8	65
27 March	1200	0.5	10.1	70
30 April	1000	3.7	9.4	70
25 May	1000	13.0	8.4	80
W-I				
1966 19 July	1500	19.0	9.3	100
15 September	1530	14.5	10.3	100
16 October	1400	4.0	9.1	95
20 December	1100	- 1.0	8.2	60
1967 26 February	1230	0.5	2.9	20
30 April	1200	2.0	0.5	< 5
25 May	0900	15.0	7.8	77

of hydrogen sulphide at W-I during February, March and April of 1967. The hydrogen sulphide enriched water would have a high biochemical oxygen demand, presumably maintaining low oxygen tensions even after the water's passage across the turbulent riffle area. The extremely low winter oxygen levels at W-I are well below the limits generally considered necessary for aquatic life. As will be described in a later section, the low winter oxygen levels markedly affect the fauna of Wandering River.

In short, the La Biche and Wandering Rivers may be described as two unpolluted rivers exhibiting different chemical characteristics, but both having their chemical conditions modified by lakes through which they flow. The temperature regime of both rivers consists of long periods of high summer temperatures and low winter temperatures, with rapid changes in spring and autumn. The La Biche River is fairly clear, well-buffered, and rich in phosphate; it appears to have good winter conditions for aquatic life. The Wandering River, in contrast, is moderately turbid and has pH and alkalinity values reflecting its bog origin. Its water is altered in winter by stagnating conditions in Lyle Lake, resulting in high sulphate levels and low oxygen content, the latter markedly affecting the fauna.

LIFE CYCLES

To understand the significance of benthic organisms in streams, they should be studied on a yearly basis. The dominant macrobenthic animals are primarily immature insects, and their presence in the river depends on the life cycle stage, i.e. egg stage, nymphal stage, adults on the wing. Standing crop and sometimes production of stream benthos are usually studied by "quantitative" methods such as the square-foot sampler, the results being expressed on a weight or number per area basis. But since seasonal changes in numbers of animals and numbers of species will cause large changes in standing crop during the course of a year, it is not surprising that accurate determinations of stream production based on weights or numbers alone have proved almost impossible to make. The often very large and sometimes unexplained variations obtained by such methods serve to accentuate the need for another approach to stream studies. The analysis of life cycles and the determination of qualitative changes within stream communities are attempts at such an approach.

In this study, life cycles were determined by studying the population structure of various species during their aquatic existence. By analysing changes from month to month, it was hoped that the pattern of growth and emergence might be determined. This approach has been applied successfully in other parts of the world (Macan, 1957; Hynes, 1961; Maitland, 1965, 1966), but it seldom has been tried in North America.

Tricorythodes minutus Needham

This mayfly (Fig. 7) was present at L-II and W-I in June, July, and August 1966. It had a very short, univoltine life cycle, characterized by rapid growth during July. There were no apparent life cycle differences

between L-II and W-I. Tiny nymphs appeared in late June 1966, grew rapidly during July, and emerged during late July and August. Large numbers of sub-imagos were present in the drift at W-I during August 3-4, 1966. Oviposition took place shortly after this, and the eggs apparently lay dormant during the subsequent nine months. The life cycle from the time of hatching to oviposition takes about six weeks and represents the shortest growth period of any insect studied in the La Biche and Wandering Rivers.

Leptophlebia cupida (Say)

This univoltine mayfly, formerly known as Blasturus cupida, was also found in both La Biche and Wandering Rivers; its life cycle will be described only for La Biche River. Small nymphs first appeared in August 1966 (Fig. 8). By April some had attained a length of 8 mm, indicating winter growth, a phenomenon that Moon (1939) also observed for two species of this genus in Great Britain. L. cupida then disappeared from La Biche River, suggesting an early emergence and supporting the observations of Clemens (1913), who described this mayfly as an early spring species in eastern Canada. However, Neave (1930), Ide (1935) and H. F. Clifford (personal communication: University of Alberta) observed unusual migratory behaviour in this species. These workers noted that in late spring the nymphs moved upstream until they encountered a tributary, which they then entered and ascended. Final development and emergence took place in the tributary, or muskeg areas associated with it. The flight period, therefore, is seemingly later than would be suspected from growth histograms restricted to the main river. It is likely that such behaviour also occurs in the La Biche River, although the actual migration was not observed.

Figure 7. Population length-frequency histograms of Caenis simulans at W-I, Tricorythodes minutus at L-II and W-I, and Taeniopteryx nivalis at L-II. Each individual histogram shows the percentage size distribution of the species during the indicated period. Horizontal dotted lines indicate that no specimens were present.

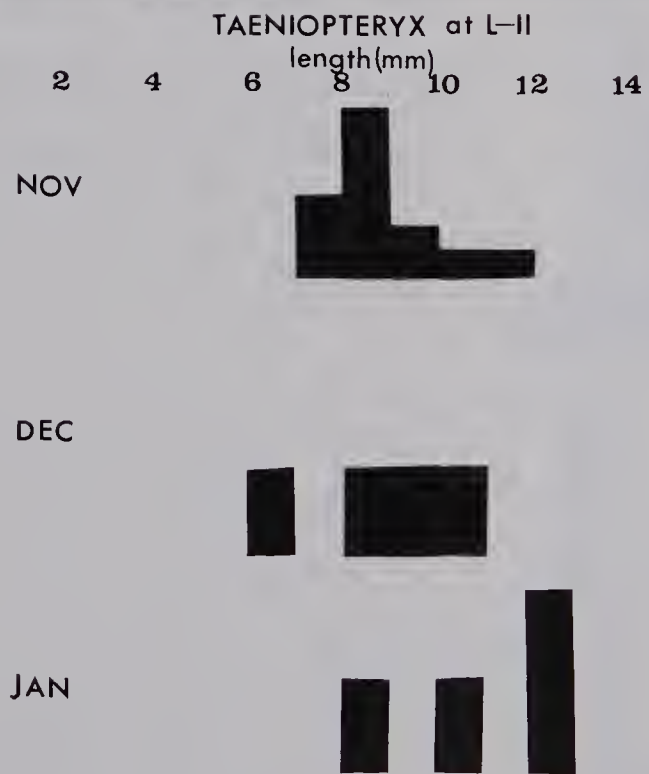
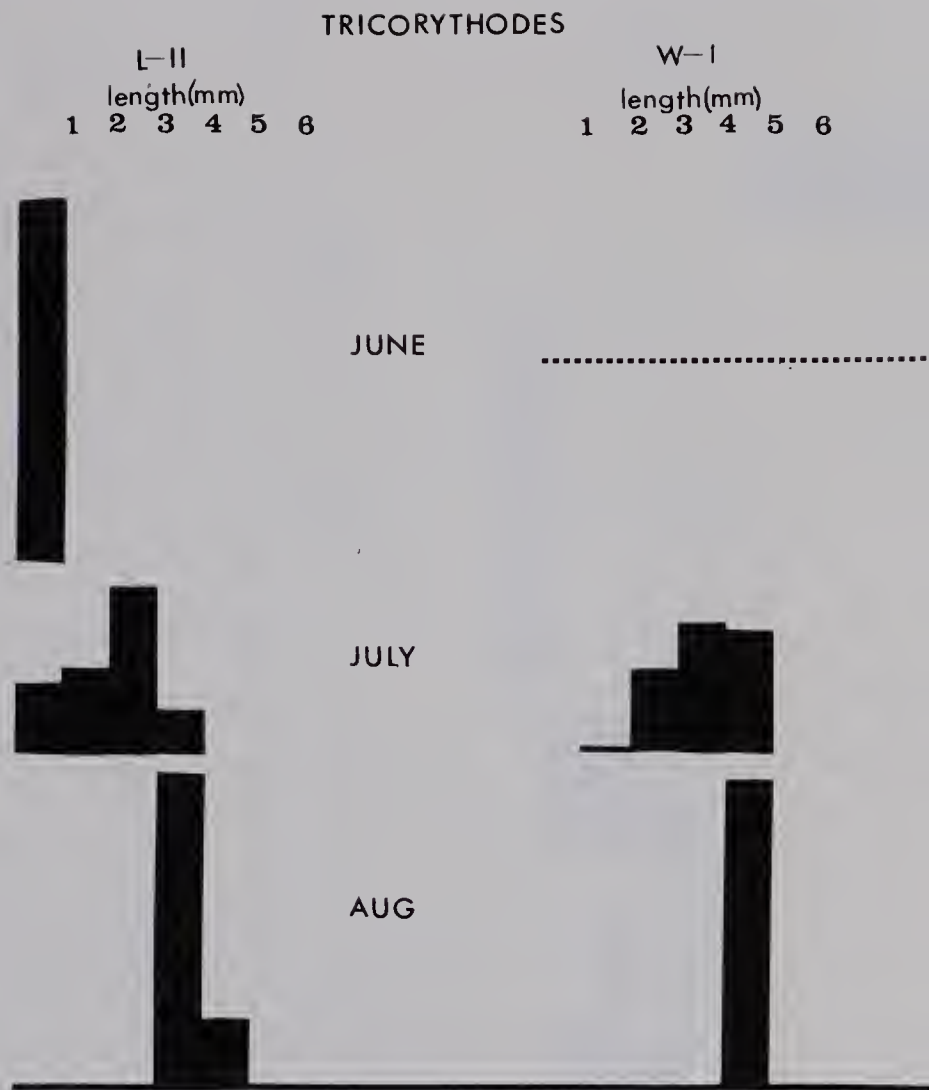
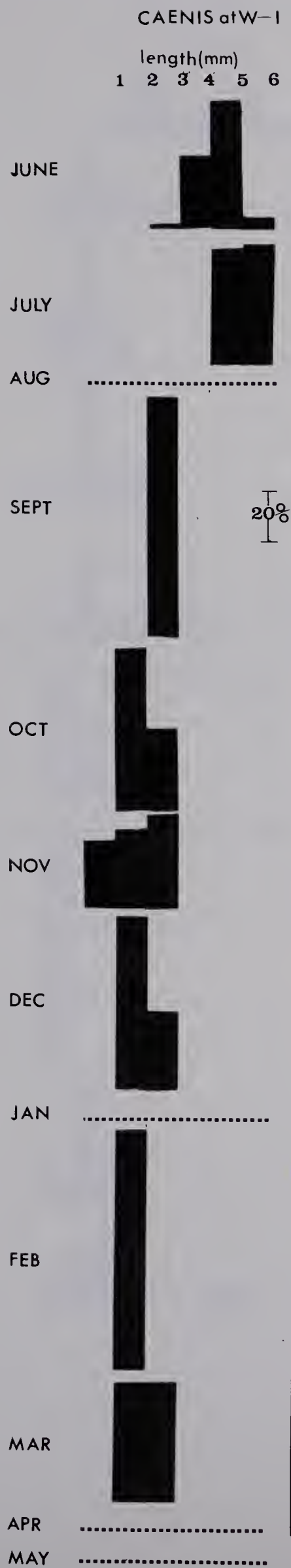


Figure 8. Population length-frequency histograms of Neureclipsis bimaculatus at W-I, and Leptophlebia cupida at L-II. Each individual histogram shows the percentage size distribution of the species during the indicated period. Horizontal dotted lines indicate that no specimens were present.

NEURECLIPSIS at W-I

length(mm)

length (mm)						
2	6	10	14	18	22	26

JUNE

JULY

AUG

SEPT

OCT

NOV

DEC to
MAR

APR

MAY

20%

LEPTOPHLEBIA at L-II

length(mm)

length (mm)										
1	2	3	4	5	6	7	8	9	10	11

MAY

**JUNE —
JULY**

AUG—
SEPT

OCT

NOV

DEC

JAN

FEB —
MAR

APR

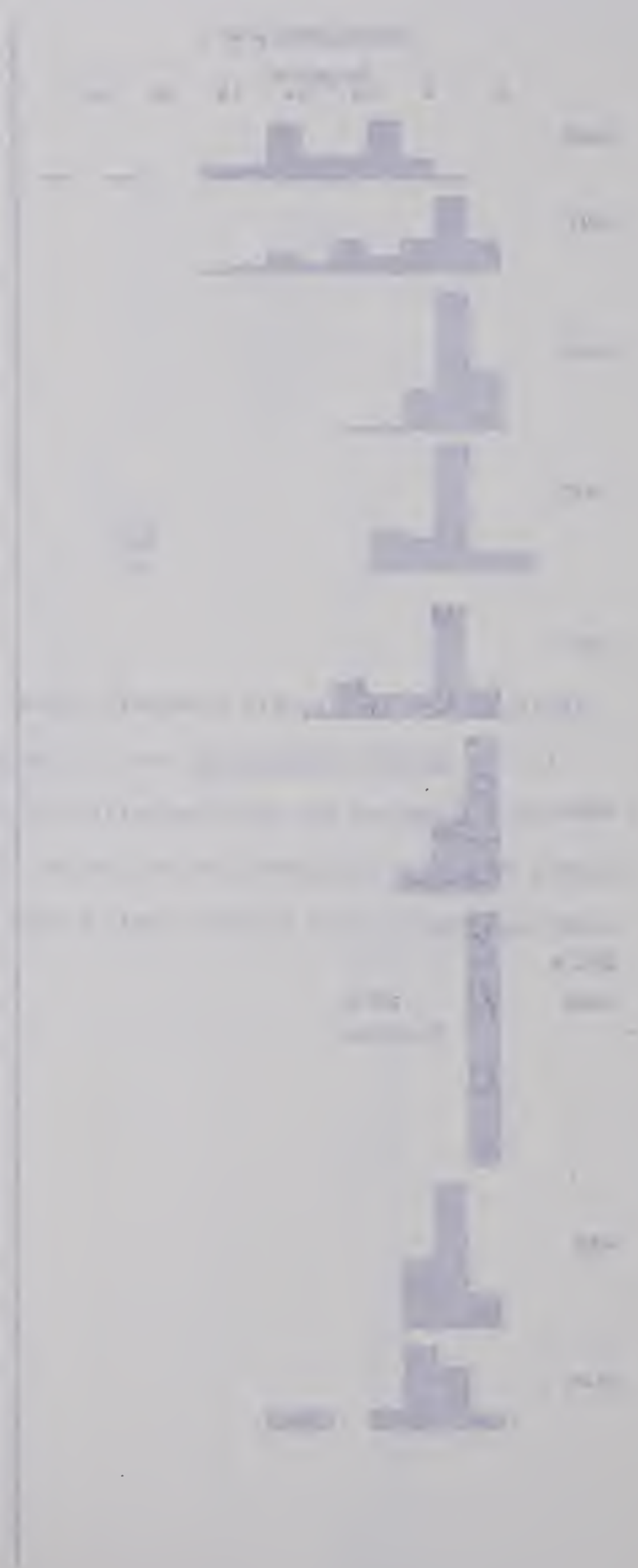
MAY

100%

Aug — Sept

100%
Dec to Mar

100%
Feb — Mar



Caenis simulans (McDunnough)

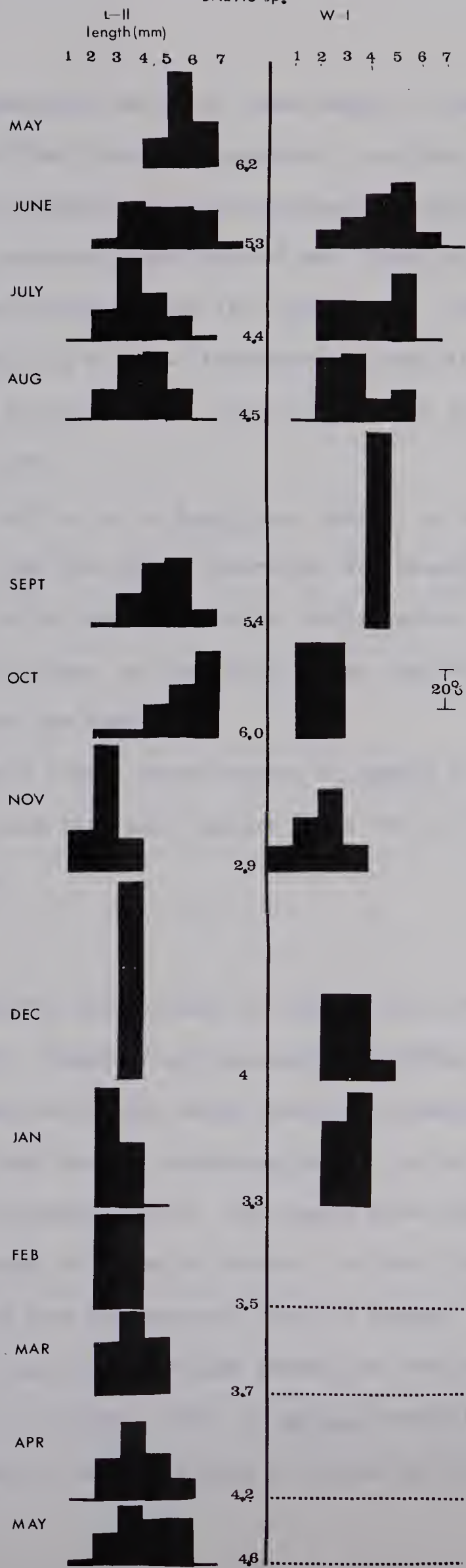
This species was found at both W-I and L-II and appears to have a univoltine life cycle similar in both rivers. Adults emerged during late June and July, 1966 (Fig. 7). Nymphs were absent during August 1966, suggesting the species was in the egg stage at this time. The eggs apparently hatched during September to November, and there was some growth in this initial nymphal period. None of the nymphs, however, exceeded 3 mm during the winter months, indicating a cessation of growth at this time. Apparently the nymphs were almost completely eliminated from W-I during the near oxygenless conditions of early spring. Clemens (1913) found nymphs of C. diminuta Walker in Ontario to be most abundant from 5 June to 30 July and observed adults from 2 July to 12 August. This agrees with observations reported here. Moon (1939), working with C. horaria (L) in Great Britain, found that the eggs hatched about six weeks after oviposition, and the nymphs stopped growing during winter. These observations also are similar to those reported here for C. simulans.

Baetis sp.

Because Baetis sp. was absent from Wandering River from February through May 1967 (Fig. 9), the life cycle initially will be described as it was observed in the La Biche River. There appear to be two generations per year, a slow-growing winter generation taking about eight months to develop to the adult, and a rapid summer generation completing its life cycle in four months. During late May and June 1966 the adults presumably emerged and oviposited, adults being collected on 20 June. The eggs appeared to hatch immediately, and the recruitment of these tiny nymphs caused the decrease in mean size during June, July, and August. These nymphs grew rapidly in summer and were ready to emerge during September and

Figure 9. Population length-frequency histograms of Baetis sp. at L-II and W-I. Each individual histogram shows the percentage size distribution of the species during the indicated period. The mean size of the specimens at L-II is shown to the right of the histogram. Horizontal dotted lines indicate that no specimens were present.

BAETIS sp.



October. The tiny nymphs appearing in November (mean length 2.9 mm) would be the offspring of the "fast" summer generation. The tiny nymphs grew slowly during the winter; growth accelerated during April and May 1967, and, by late May 1967, the mean length was 4.6 mm. This is almost 2 mm shorter than the mean length for the May 1966 generation. But there was a late spring in 1967 resulting in water temperatures lower in April and May 1967 than in the same period of 1966, and this probably accounted for the smaller nymphs of May 1967.

In Wandering River, the life cycle of Baetis sp. appears to be similar to the above, except that the winter generation was missing from February to May 1967. It is quite possible that the environmental stresses of late winter in this river, as described in the chemistry section, temporarily eliminated the species.

Both Macan (1957) and Hynes (1961) found species of Baetis in Britain having bivoltine life cycles, and this also appears to be the situation in La Biche and Wandering Rivers.

Taeniopteryx nivalis Fitch

This stonefly, one of the few plecopterans of the La Biche system, was found only at station L-II. Nymphs first appeared in November 1966 (Fig. 7). The November nymphs were fairly large, and it is possible that they were either present but very tiny in preceding months, or the species was in the egg stage in the preceding months. The nymphs grew during early winter, reaching a maximum length of 13 mm in January, at which time they exhibited fully developed wing pads and appeared ready to emerge. Nymphs were not present in any later samples. Although stoneflies have been reported emerging under the ice (Sailer, 1950), T. nivalis probably did not emerge until the ice broke up, as adults were collected at another

location about 300 km to the southwest in April (personal communication: H. F. Clifford, University of Alberta). T. nivalis, therefore, is univoltine, with rapid mid-winter growth and an early emergence. Claassen (1931) found nymphs of this genus to be univoltine in Illinois, with emergence in February and early March.

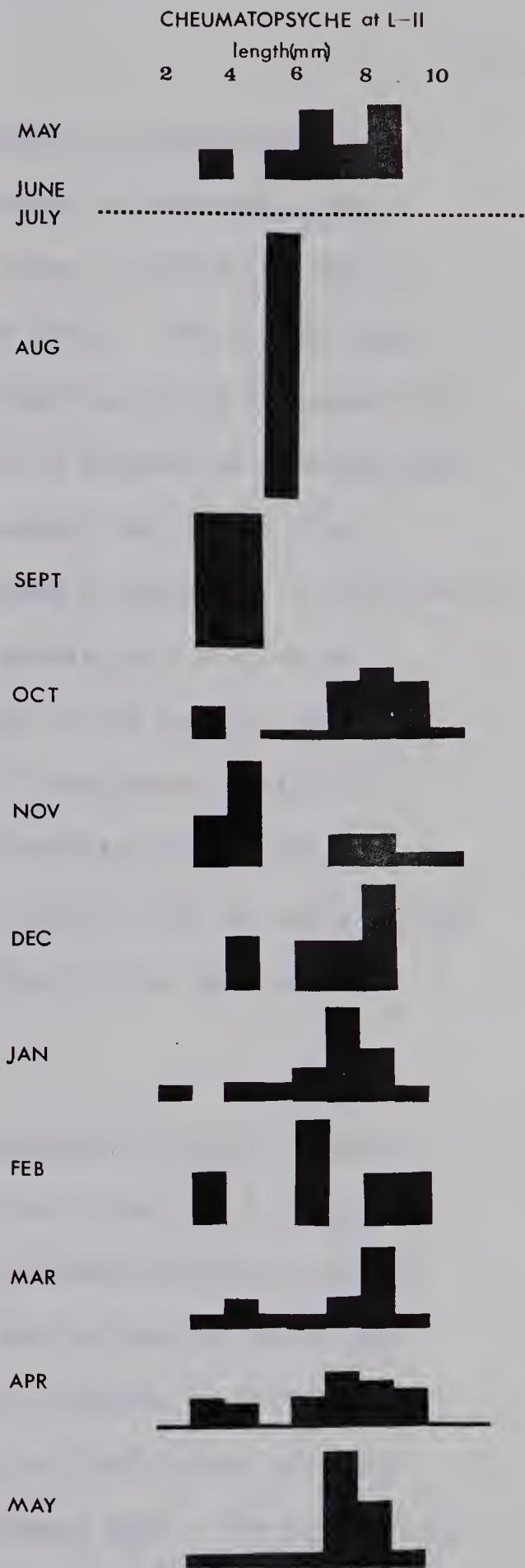
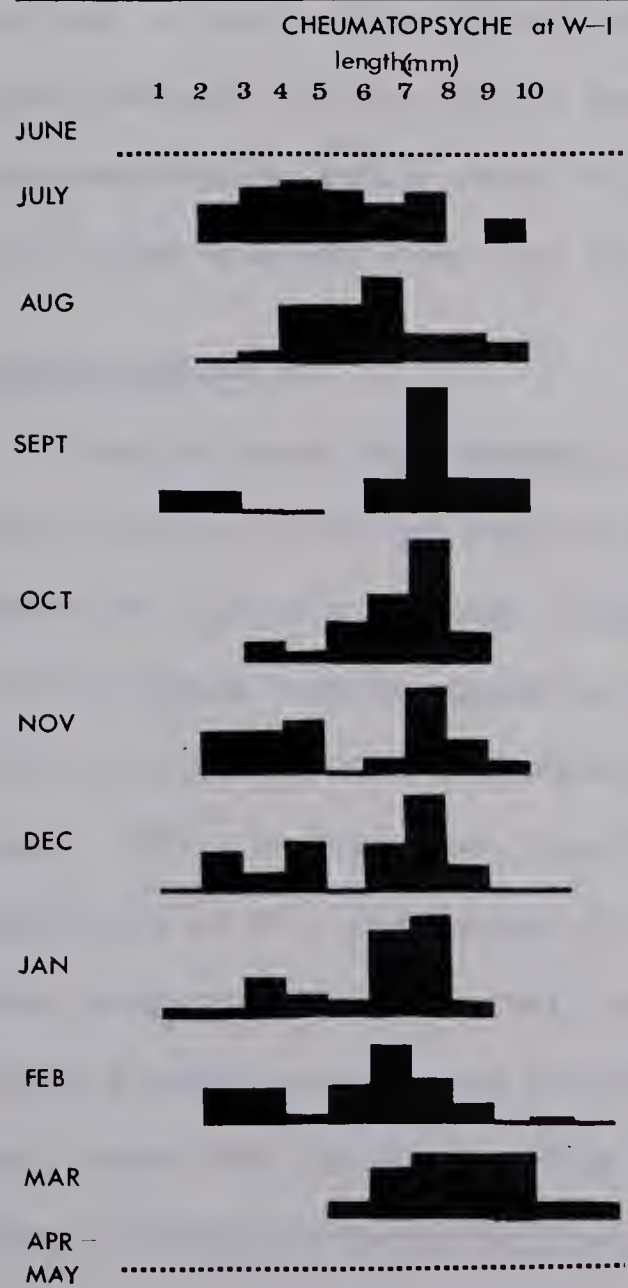
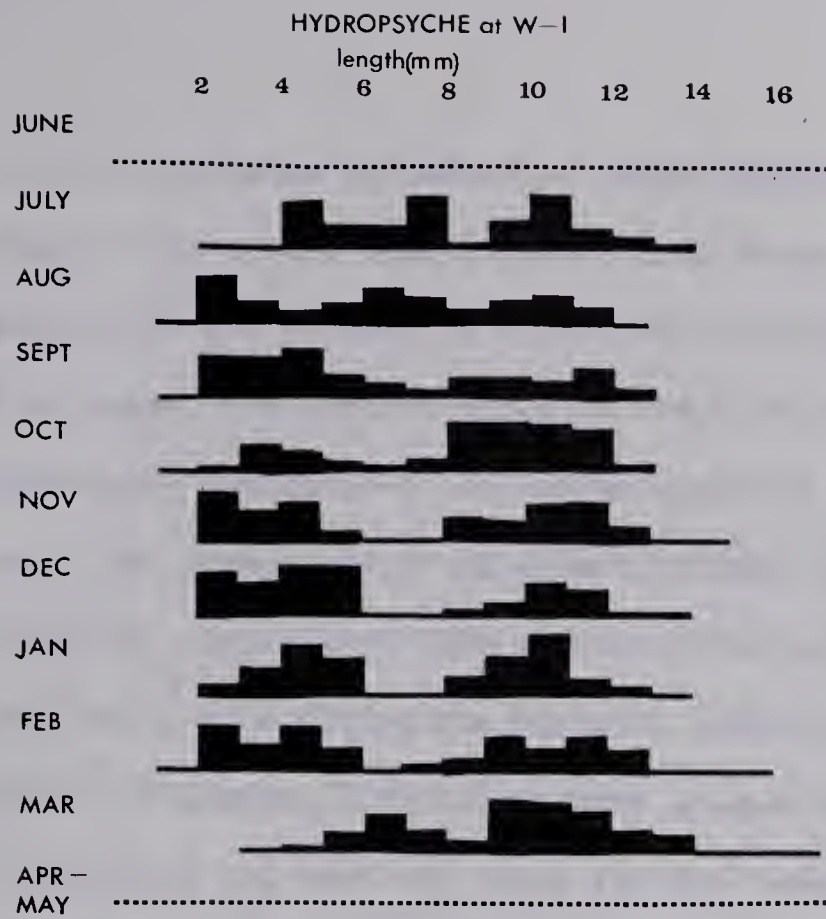
Neureclipsis bimaculatus (L.)

This psychomyiid caddis fly, only rarely encountered in La Biche River, was one of the chief bottom organisms in Wandering River. Adults were taken at W-I during June, July, and August 1966. Fig. 8 shows a recruitment of tiny larvae in July 1966, indicating that the eggs hatched rapidly after ovipositing. The large numbers of size groups throughout the year seems indicative of delayed hatching of eggs, but it may be due to an extensive ovipositing period. There was apparently some growth during late summer, and a major recruitment of small larvae in November. The few larvae taken in samples during the winter months apparently underwent little growth at this time. N. bimaculatus was one of the few macrobenthic organisms able to survive the severe winter conditions at W-I. Growth resumed or accelerated during April and May 1967, and by June, just prior to emergence, larvae were at maximum length. The life cycle is, therefore, univoltine at W-I with a late summer flight period, rapid hatching of eggs, and growth primarily in autumn and spring.

Hydropsyche recurvata Banks

Imagos were collected during July and early August in Wandering River and during June in La Biche River. For Wandering River, there was a very large size range in all seasons with small larvae present each month (Fig. 10). In July 1966 there were few small larvae, but the percentage of

Figure 10. Population length-frequency histograms of Hydropsyche recurvata at W-I and Cheumatopsyche sp. at L-II and W-I. Each individual histogram shows the percentage size distribution of the species during the indicated period. Horizontal dotted lines indicate that no specimens were present.



smaller specimens increased in August and September, as presumably the eggs of the summer started hatching. From November to February, the population was binodal in structure, with one group of larvae in the 2 to 6 mm range, and another group in the 9 to 14 mm range. The latter group presumably was composed of larvae hatching during August and September 1966. while the former group would have hatched later in autumn—in November and December. Hence there was growth during late summer and autumn, but apparently none during the winter. Growth resumed in March 1967; and then in April, coinciding with the intense stagnating conditions, the larvae disappeared and were not found for the remainder of the regular study period. A sample taken at W-I during July 1967 (not shown on Fig. 10), again contained larvae, with a surprisingly large size range. Since upstream recolonization seems unlikely, it is possible that in early spring the larvae underwent some type of aestivation deep in the substrate.

Cheumatopsyche sp.

Fig. 10 shows the changes in the larval populations of this caddis fly in both La Biche and Wandering Rivers. As was found for H. recurvata, there was a large size range of Cheumatopsyche present during all months. The histograms indicate pupation or emergence during June and July, and this was substantiated when several adults were collected at W-I in early August 1966. In September, there was an influx of tiny larvae into the population at W-I, indicating the hatching of summer eggs. The population size groups remained relatively unchanged throughout the winter, exhibiting a weak binodal structure in Wandering River. In March growth resumed in both rivers and continued through the spring and summer months in La Biche River. However in Wandering River, as was found for H. recurvata, Cheumatopsyche sp. disappeared in April and was not found for the remainder of the study period.

The binodal structure of the Hydropsyche-Cheumatopsyche populations in winter could be advantageous in exploiting the food available at this time. Both genera are mainly omnivorous net feeders, and they probably are selective as to particle size. During winter, when food particles are at minimal levels, there is one size group (2-6 mm) of H. recurvata and Cheumatopsyche sp. that can exploit small food items; another size group (9-14 mm) of H. recurvata that can feed on the large food particles; finally a third size group (6-10 mm) of Cheumatopsyche sp. that exploit intermediate size food items.

COMPOSITION OF MACROBENTHOS

La Biche River

Figure 11 shows the percent composition of the macrobenthos at L-II from June 1966 to May 1967. In interpreting this graph, one must recognize that monthly changes in percent composition may be due either to a true increase in the number of animals of one species or to a decrease in the numbers of other organisms. For this reason, knowing the life cycles of the animals is valuable. By combining life cycle knowledge with composition data, an accurate account of seasonal changes is possible.

In June 1966, the dominant organism of the La Biche River was Hyalella azteca (Saussure). The large numbers at this time were attributed to the influx of immature forms into the population, due to spring and early summer reproduction. Next in abundance were the mayfly Baetis sp. and filter-feeding simuliid larvae (Simulium vittatum Zett. and S. venustum Say). Gammarus lacustris Sars also was present in June, but comprised only a small part of the community.

The most striking change from June to July was the increase of Gammarus lacustris. Its July peak was due to the influx of the new generation into the population at this time. Menon (1966) also described a numerical peak in July for this amphipod in a small central Alberta lake. Noticeable during July was the percentage increase of Baetis nymphs. Life cycle data (Fig. 9) indicate that this is an absolute increase in numbers, caused by the appearance of tiny nymphs of the summer generation. Tricorythodes minutus, which was present only in June, July and August, also was at maximal numbers in July.

In August and September, G. lacustris and H. azteca were still major constituents of the fauna, and, due to the summer generation, the Baetis population reached its peak at this time.

Figure 11. Seasonal percentage composition of macrobenthos at L-II from June 1966 to May 1967. Only those organisms comprising at least 2% of the fauna in one monthly sample are included. The width of the spindle is proportional to the number of specimens taken on the sampling date. A narrow horizontal line indicates that the organism was present but comprised less than 2% of the monthly total.

J J A S O N D J J F M A M

NEMATODA



BAETIS



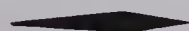
CORIXIDAE



HYALELLA



TAENIOPTERYX



HYDROPSYCHE



HEPTAGENIA



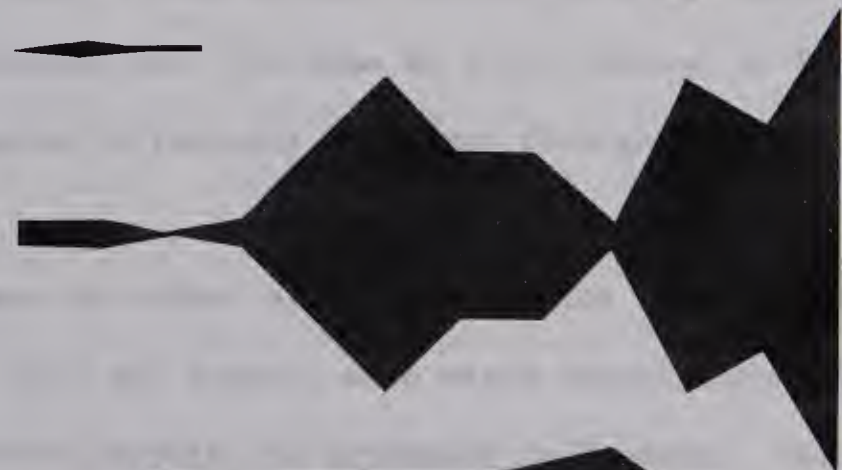
CHEUMATOPSYCHE



TRICORYTHODES



SIMULIUM



DUGESIA



GAMMARUS



TENDIPEDIDAE



CAENIS



By November the number of taxa had increased with the appearance of groups that were in the egg stage during the summer. Hydropsychidae were common; adult corixids had increased to their autumnal maximum; Simulium exhibited a percentage increase due, in part, to the recruitment of overwintering S. vittatum larvae. Baetis sp. and G. lacustris were less important; the former because of emergence of the summer generation, the latter because of the death of the old generation.

The period of December to March, characterized by almost total darkness under the ice (Wright, 1964), was the main winter period in La Biche River. There was little change in percent composition during the winter. The dominant organisms were H. azteca, Simulium sp. and Tendipedidae, collectively making up 76.2% of the total sample.

During April the river became ice-free, and the number of taxa increased; but this increase is due in part to more adequate samples at this time. The dominant organisms were the same as those present in March. Percent composition remained relatively unchanged through May, the end of the study period.

There were variations in number of taxa during the various seasons of the year. For June, July and August, when water temperatures were high, an average of ten taxa were present; in September to November, there were 15 taxa; during December through March, 16 taxa; in April and May, 17 taxa occurred. The number of taxa was highest in spring after the river had become ice free. At this time water temperatures were low and dissolved oxygen content high. During the summer months, many of the spring insects had emerged, and their new generations were present in the river mainly as eggs. In contrast to the spring and summer period, there is little change in the community during the winter months under the ice cover.

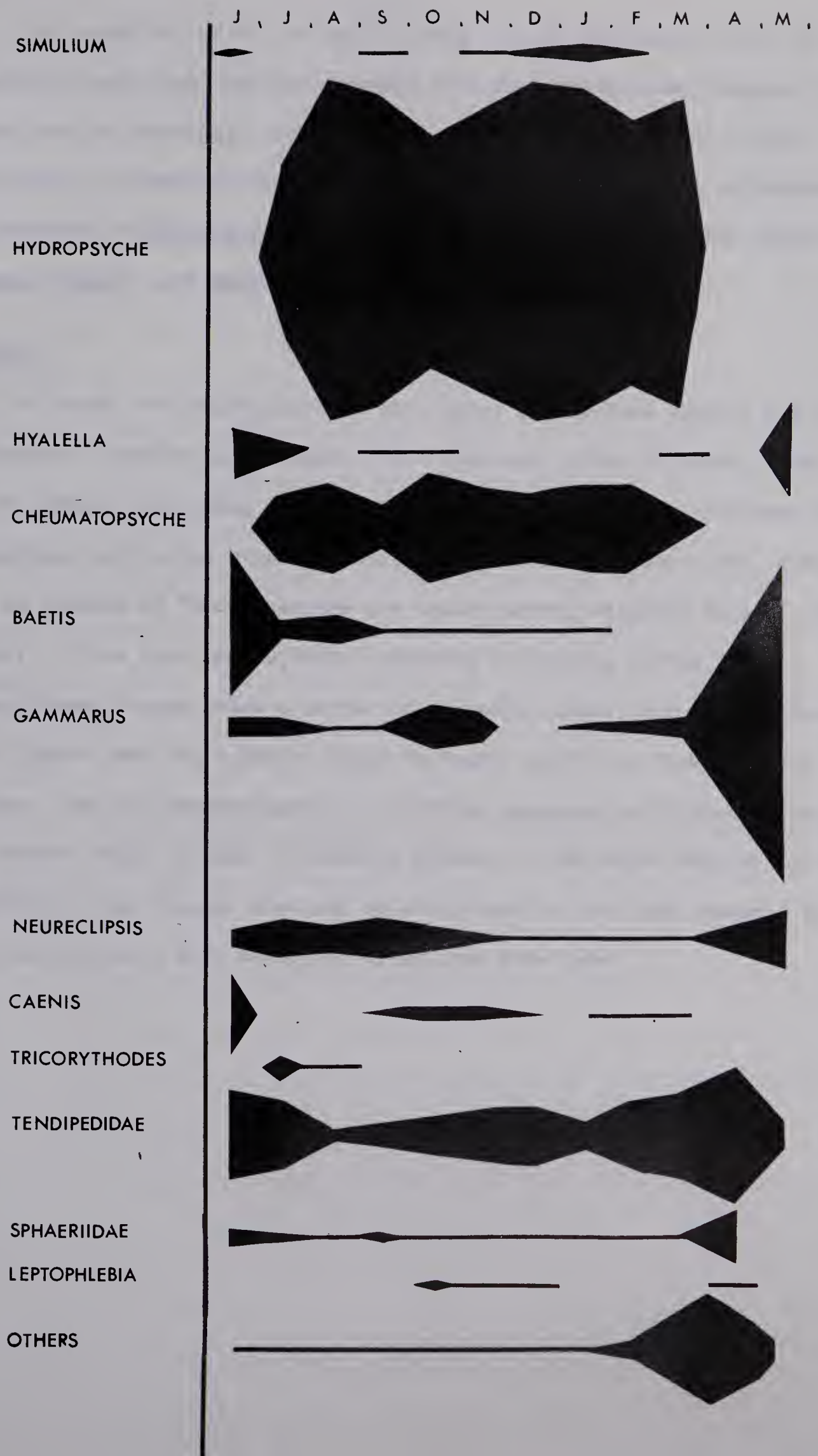
Wandering River

The macrobenthic composition at W-I (Fig. 12) was markedly different from that encountered at L-II, and these differences are due mainly to the large numbers of net-feeding organisms found at W-I. During most of the year the fauna is composed mainly of two net-feeding hydropsychids, a net-feeding psychomyiid, and tendipedid larvae. All these animals apparently thrive here by feeding on large amounts of suspended material present in the effluent water from Lyle Lake.

In contrast to La Biche River, amphipods were never a large component of the fauna at W-I. Tendipedidae were present in every month, a contrasting situation from L-II where they were absent during the summer months. Baetis sp. was present at W-I only from June to February and was a relatively minor component except during June, when it made up 28% of the total macrobenthic fauna. This, however, was due primarily to the lack of hydropsychids at this time. Compared to La Biche River, where many species contributed substantially to the percent composition, Wandering River had a rather limited fauna. Although mayflies, blackflies, amphipods, nematodes, etc. were present, they were generally found in small numbers.

The most striking seasonal changes at W-I were due to the downstream effects of winter stagnation in Lyle Lake. In early spring 1967, when winter stagnation was at its height, and dissolved oxygen was reduced to 0.5 ppm, the fauna was limited mainly to tendipedids, amphipods, elmids, beetles, oligochaetes, and finger-nail clams. Although two trichopterans, Neureclipsis bimaculatus and Psychomyia sp. also were present at this time, Hydropsyche and Cheumatopsyche were eliminated. This is surprising because Roback (1962) indicates Hydropsyche and Cheumatopsyche to be eurytopic caddis flies, surviving in low oxygen, high turbidity, sulphate, etc.

Figure 12. Seasonal percentage composition of macrobenthos at W-I from June 1966 to May 1967. Only those organisms comprising at least 2% of the fauna in one monthly sample are included. The width of the spindle is proportional to the number of specimens taken on the sampling date. A narrow horizontal line indicates that the organism was present but comprised less than 2% of the monthly total.



The situation at W-I in early spring can be considered a type of "natural" pollution, and the presence of pollution-tolerant forms at this time, such as amphipods, oligochaetes, and tendipedid larvae, is not surprising. These pollution-like conditions in early spring eliminated, in addition to Hydropsyche and Cheumatopsyche, such clean-water forms as Baetis, Caenis, and Simulium.

Biomass

Although the inadequacies of the Surber square-foot sampler are well documented (Needham and Usinger, 1956; Armitage, 1958; Clifford, 1966) a few samples were taken from the Wandering River (W-I) for purposes of comparison with other studies. During August and September 1965, there was an average of 7100 organisms per square metre, weighing 95.5 g. This number is less than the 13,460/m² recorded by Cushing (1963) for a Saskatchewan stream below a series of eutrophic lakes; but it was considerably higher than the 4,568/m² found by Gauvin (1959) in Utah mountain streams, and the maximum number of 1,296/m² measured by Clifford (1966) in certain Ozark streams of southern Missouri. The above samples for W-I indicate a high biomass that can be attributed to the large amounts of food material draining into Wandering River from Lyle Lake.

PLANKTON

A few very large rivers like the Nile may support a true plankton population (Hynes, 1960); however, it is generally considered that most river and stream plankters are accidental, e.g. they have been introduced from lakes or backwaters, or they have been removed from aquatic macrophytes or rocks due to the scouring action of the water current. This type of river "plankton" is sometimes called tychoplankton, and it was sampled in the La Biche and Wandering Rivers during summer 1966 using a membrane filtration technique (McNabb, 1960). A known volume of river water was filtered through a membrane filter, the filter cleared with cedar oil, and the plankton counted in 30 fields.

The planktonic community at W-I was richer both in numbers and species than its counterpart in the La Biche River (Table V). Comparing samples taken at W-I (below Lyle Lake) with those at W-II (above Lyle Lake) indicates that the large numbers of planktonic organisms at W-I probably originated in Lyle Lake. The major planktonic organisms in Wandering River were Fragilaria sp., Anabaena sp., and rotifers; in La Biche River Cocconeis sp. and other diatoms were the most abundant plankters.

The large amounts of plankton entering Wandering River from Lyle Lake maintain large populations of net-feeding insect larvae at W-I. On the debit side, however, the large amount of plankton in the form of oxidizable organic matter contributes to the stagnating winter conditions. La Biche River receives less plankton from Lac la Biche, and net-feeders are less common here. They are replaced mainly by mayflies that feed on epiphytic diatoms.

Table V: Plankton numbers of La Biche and Wandering Rivers during the summer of 1966.

<u>Station</u>	<u>Date</u>	<u>Total Number/ml</u>
W-I	24 June	436
	20 July	477
	17 August	454
W-II	24 June	20
	20 July	59
L-I	23 June	84
L-II	20 July	26
L-III	13 July	10
	20 July	262
	17 August	12

DRIFT OF STREAM INVERTEBRATES

The importance of invertebrate drift in lotic environments has been realized only recently. Several workers (Müller, 1954, 1963; Morgan and Waddel, 1961; Elliott, 1965; Anderson, 1967) have shown that drift rates may vary considerably with both time of year and time of day. Observations of continual downstream displacement of benthic organisms led to the postulation of a "colonization cycle" by Müller (1954). This was an attempt to explain the presence of certain organisms in headwaters of streams when the downstream drift suggested that the upstream area at some time should be depleted. Müller hypothesized that aquatic insects flew upstream after emergence and oviposited in the stream headwaters, thus counteracting the loss by drift. Roos (1957) added further evidence for the correctness of the colonization cycle when he quantitatively described the upstream flight (presumably leading to oviposition in the headwaters) of adult aquatic insects after emergence.

Organisms that are entirely aquatic, e.g. amphipods, also may have substantial drift rates, and an upstream flight cannot explain their distribution throughout the stream system. Their presence in headwater regions was explained, in part, by Minckley (1964) when he reported upstream movements "en masse" of one species of amphipod (Gammarus bousfieldi Cole and Minckley) in Kentucky, and suggested that the other species of amphipods present might populate upstream reaches by less spectacular and shorter movements.

I took drift samples from the Wandering River to investigate both spatial and temporal differences in drift composition. The drift nets (10 meshes/cm) had apertures of 30.4 cm², and each was so attached to two solidly anchored metal rods that the upper edge of the opening was slightly

above the water's surface. With respect to spatial differences, I placed single drift nets at station W-I at 1525 hrs. and W-II at 1535 hrs., 19 July 1966, and emptied them at 0855 hrs. and 0905 hrs., 20 July 1966. For temporal differences, I placed two drift nets, side by side, at W-I, and emptied them every three hours. This experiment was carried out for a 24 hour period, starting at 0900 August 3, 1966 and ending at 0900 hours August 4, 1966.

Wet weights of organisms (blotted on filter paper) were used in analysis of the temporal composition primarily because of the very large numbers of lake-dwelling Chaoborus present in the drift. If calculated as percent numbers, Chaoborus would mask the presence of the other groups.

Spatial Differences

Drift composition indicated differences between W-I and W-II (Table VI). At W-II, above Lyle Lake, the drift was composed chiefly of the burrowing mayfly Hexagenia limbata (Serville), a common inhabitant of the sandy substrate type of this region. Other ephemeropterans, Ephemerella sp. and Callibaetis sp., were encountered only at W-I, while Baetis sp. and Heptagenia sp. were present at both stations. Both the amphipods Hyalella azteca and Gammarus lacustris were present in large numbers at W-I, but only the former was present at W-II. Hydropsychid larvae and nymphs of Tricorythodes minutus were present at both stations, although in greater numbers at W-I.

There are physical and chemical differences between these stations that might account for the dissimilarities in their drift composition. The W-I station is located about 1.5 km below the small, eutrophic Lyle Lake, in a region of the river that is shallow and rocky. In contrast, W-II is

Table VI: Composition of drift fauna, Wandering River, 19-20 July 1966.

<u>Taxa</u>	<u>No.</u>	<u>% No.</u>	<u>Wt. (g)</u>	<u>% Wt.</u>
W-I				
Hydropsychidae larvae	280	10.50	2.91	18.00
<u>Neureclipsis</u> sp.	30	1.12	0.21	1.30
Diptera pupae and larvae	882	33.04	4.15	25.66
Hydropsychid and dipteran adults	55	2.05	0.53	3.28
Coleoptera	6	0.22	0.43	2.66
Amphipoda	1024	38.36	6.61	40.88
Corixidae	88	3.29	0.24	1.48
<u>Hexagenia limbata</u>	0	0	0	0
Other Ephemeroptera	290	10.86	0.84	5.19
Others	<u>15</u>	<u>0.56</u>	<u>0.25</u>	<u>1.55</u>
Total	2670	100.00	16.17	100.00
W-II				
Hydropsychidae larvae	8	5.09	0.08	6.90
Diptera pupae and adults	20	12.74	0.02	1.72
Amphipoda	14	8.92	0.04	3.45
Corixidae	25	15.93	0.23	19.83
<u>Hexagenia limbata</u>	29	18.47	0.59	50.86
Other Ephemeroptera	51	32.48	0.18	15.52
Others	<u>10</u>	<u>6.37</u>	<u>0.02</u>	<u>1.72</u>
Total	157	100.00	1.16	100.00

above Lyle Lake in a region of the river that is deep, soft-bottomed and drains a predominantly bog region. Water analyses of 20 July 1966 at these stations (Table VII) indicate nutrient depletions as the river flows from W-II to W-I. Much of this probably occurs in Lyle Lake and results in an increased amount of organic matter leaving the lake, i.e. the uptake of nutrients by phytoplankton results in production of organic matter. The effect of this organic enrichment is seen at W-I where there are large numbers of filter-feeding insect larvae, which are virtually absent at W-II. The wet weights of drift organisms from W-I and W-II were 16.17 g and 1.16 g respectively, and much of this difference can be attributed to the enrichment of the river as it passes through Lyle Lake.

Dip-net samples at W-I during this period showed the benthos to be composed primarily of hydropsychid larvae. The larger numbers of amphipods present in the drift when compared to the dip net samples indicates that many of the amphipods are originating in Lyle Lake and "drifting" considerable distances downstream. Müller (1963) and Waters (1965) also observed amphipods drifting long distances, particularly at night. Although dip-net samples contained few organisms at W-II, large numbers of animals were collected in drift nets. Drift sampling is perhaps a better way, therefore, of collecting organisms in rather poorly productive areas.

Temporal Differences

Diurnal variations in the activities of aquatic organisms have been observed for several groups, especially the diel migrations of lake-dwelling Chaoborus and certain entomostracans. Recent studies of Tanaka (1960), Waters (1962) and Müller (1963) indicate important diurnal periodicities for certain stream invertebrates, viz. night-time drift is greater than

Table VII: Water analyses at W-I and W-II, 20 July 1966 at 1100 hrs.
All units are reported in ppm except turbidity, which is
reported in Jackson units.

	<u>W-I</u>	<u>W-II</u>
Total alkalinity	60	110
Hardness	40	35
Turbidity	35	45
Silica	2.30	5.60
Nitrite	0	0.005
Total phosphate	0.25	0.60
pH	7.7	7.3

drift during the day. An increase in activity, of course, brings the organisms into contact with strong water currents and hence into the drift. Table VIII shows the changes in drift composition during a single 24 hour period at W-I. Water temperatures at this time varied from 19° C (1800 hrs.) to 16° C (0600 to 1200 hrs.). Sunset was at 2030 hrs. on 3 August, and sunrise was at 0453 hrs. on 4 August. There was no precipitation during the period.

The major components of the drift were the culicid Chaoborus sp. which originated in Lyle Lake; the amphipods Gammarus lacustris and Hyalella azteca; emerging mayflies, almost exclusively Tricorythodes minutus; tendipedid larvae, pupae and adults; Corixidae; adult trichopterans, mainly Neureclipsis bimaculatus, with a few Hydropsyche recurvata and Cheumatopsyche.

Adult trichopterans were the most prevalent forms during daylight, being replaced after sunset by amphipods (Fig. 13). Ephemeropteran sub-imagos (Tricorythodes) were also a major component, but only during the early morning.

A short, early morning emergence period can account for the periodicity of the sub-imago mayflies. Adult caddis flies, however, can live for several days before ovipositing, which is usually carried out under water. Hence their periodicity might be due to either ovipositing or emergence activities. Fremling (1960) distinguished between ovipositing and emergence activity of caddis flies by calculating sex ratios: namely, sex ratios close to unity indicate emerging activity, whereas a greater proportion of females would denote ovipositing activity. The sex ratio in my study was slightly skewed in favor of males, indicating the caddis fly periodicity was due to emergence activity.

Table VIII: Composition of drift at W-I, 0900 August 3 to 0900 August 4, 1966.

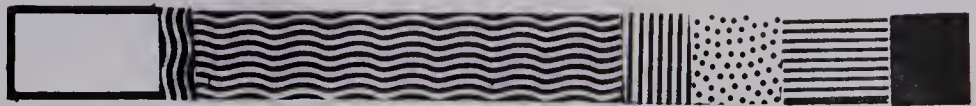
Taxa	% Weight								% Total
	0900- 1200	1200- 1500	1500- 1800	1800- 2100	2100- 2400	0000- 0300	0300- 0600	0600- 0900	
<u>Chaoborus</u> sp.	15.1	13.7	25.5	26.6	4.7	9.7	23.2	14.2	20.1
Amphipoda	3.5	11.7	9.6	5.9	47.8	38.7	28.4	4.4	17.5
Adult Trichoptera	45.1	53.4	46.9	46.5	19.7	23.3	1.6	22.2	30.3
Ephemeroptera sub-imagos	7.9	3.5	0	2.3	0.3	0.4	0	28.0	2.9
Tendipedidae pupae, larvae, adults	9.1	6.7	3.1	4.8	17.1	11.8	15.4	12.9	9.3
Gastropoda	2.3	0	0.7	1.1	0.1	0	15.5	0	5.6
Hirudinea	1.7	0	0.7	0.4	0.5	3.6	1.9	0.1	1.1
Corixidae	11.2	4.9	7.4	6.9	2.6	5.4	8.9	14.7	7.8
Hydropsychidae and Psychomyidae larvae	1.6	0.3	1.6	0.4	2.6	5.4	2.2	0	1.6
Ephemeroptera nymphs	0.6	0.6	1.1	1.0	1.8	1.2	1.3	0.1	1.1
Others	1.9	5.3	3.4	0.6	0.1	0.5	1.8	3.1	2.8

Amphipod periodicity at W-I (Fig. 13) probably was due to increased feeding at night, decreased feeding in the day, or both. In Wandering River most of the drift net amphipods probably came from Lyle Lake, since regular monthly dip-net samples at this time contained few specimens.

Chaoborus larvae from Lyle Lake, one of the major drift organisms, exhibited no definite diel pattern in this study. Stahl (1966) and Teraguchi and Northcote (1966) observed that early Chaoborus instars were entirely planktonic, while later instars dwelled on the bottom during the day and close to the surface at night. The fact that Lyle Lake is very shallow, perhaps too shallow for extensive migrations, might be important here.

Figure 13. Variation in drift fauna composition at W-I during the period 0900 hrs. August 3, 1966 to 0900 hrs. August 4, 1966. The entire horizontal bar of each time period represents 100%.

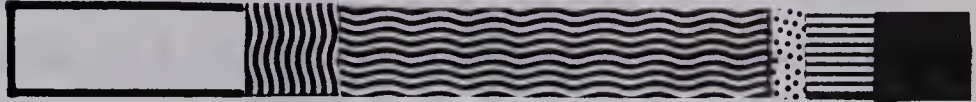
0900-1200



1200-1500



1500-1800



1800-2100



2100-2400



0000-0300



0300-0600



0600-0900



Chaoborus

Amphipoda

Adult Trichoptera

Ephemeropteran sub-imagos

Tendipedidae

Corixidae

Others

SIMULIIDAE

As chemical control for black flies is being contemplated in the La Biche watershed, the distribution of larvae is briefly noted here. The only blackfly larvae encountered during this study were Simulium vittatum Zett. and S. venustum Say. Their presence during winter was due to overwintering larvae of S. vittatum. Fredeen and Shemanchuk (1960) report S. venustum to overwinter in the egg stage.

In La Biche River, larvae are most prevalent in the rubble-sandy areas, especially where extensive Potamogeton growths occur. These areas are located in the initial steep gradient region of the river (Fig. 4), starting below L-I and ending just below L-II. Although larvae occur farther downstream, their numbers are insignificant when compared to the large numbers encountered in the above-mentioned weedy regions.

In the Wandering River there is no apparent zonation, larvae being present wherever conditions are suitable for their attachment.

S. arcticum Mall., which is likely the main agricultural pest species in northern Alberta, was never encountered, as larvae, in the La Biche River system. The immature stages of this species are probably restricted to the Athabasca River.

SUMMARY AND DISCUSSION

Physical and chemical conditions in the La Biche and Wandering Rivers are stable during late spring, summer and autumn. Because Lac la Biche does not undergo severe winter stagnation, conditions remain relatively stable during the period of ice cover in this river. The Wandering River, however, presents a markedly different winter situation. Lyle Lake is a shallow, eutrophic lake, which has a heavy summer plant growth consisting of phytoplankton, duckweed, and rooted aquatic plants. The large amount of organic matter during the long periods of ice cover results in intensive winter stagnation. Lakes of this type are numerous in northern Canada and are characteristically low in dissolved oxygen during winter; in extreme cases, they produce free hydrogen sulphide (Cooper and Washburn, 1946; Hauptman, 1958; Kerekes and Nursall, 1966).

During most of the year, the W-I riffle below Lyle Lake supported large populations of net-feeding insect larvae. But during the winter, chemical conditions gradually approached those usually encountered in cases of organic pollution (Hynes, 1960); dissolved oxygen content dropped markedly and sulphate content rose. The dominant macrobenthic caddis larvae were eliminated, and only pollution-tolerant forms such as oligochaetes, amphipods, and tendipedid larvae remained. The influence of Lyle Lake on Wandering River, therefore, varied considerably with the season, from a mild organic enrichment during most of the year, to a deleterious effect in late winter.

Life Cycles

Since chemical conditions are stable throughout the year in La Biche River, discussions of insect growths and emergence will be restricted to this stream. Of eight species investigated (Table IX), all but Taeniopteryx

nivalis are "summer species", i.e. they are present and growing mainly during the warm months as compared to "winter species", which survive high summer temperatures in the egg stage, grow during winter, and emerge in spring. T. nivalis, the stonefly, has a growth pattern similar to those described by Brinck (1949) for Swedish stoneflies, i.e. it survives high summer temperatures as an egg or non-growing nymphula, grows in winter, and emerges in early spring. Leptophlebia cupida and Baetis sp. also appear to grow during the winter. The only species growing exclusively during the summer are Tricorythodes minutus and the summer generation of Baetis sp. All other species require several months for growth, which is accomplished in spring, summer, and autumn, but not in winter.

It might be mentioned here that there are, in addition to what was presented on p. 28, other possible interpretations of the life cycle pattern of Baetis sp. The small nymphs of June and July may be the result of non-growing, very small overwintering nymphs, or even eggs in a winter resting stage. If such were the case, this species would be univoltine with a delayed hatching or growth period. Nymphs, however, were present during the whole winter and were growing again by April. While the lack of small nymphs during May could be due to the species being in the egg or nymph stage at this time, I cannot explain why they should take so long to resume growth, when other nymphs of the same species have been growing since April. Other possibilities, such as three generations in two years, a phenomenon not unknown in mayflies, or perhaps even two species being present, cannot be positively discounted.

Table IX: Life cycle patterns of the major macrobenthic insects of W-I and L-II, 1966-1967.

<u>Species</u>	<u>Egg</u>	<u>Hatching</u>	<u>Growth</u>	<u>Emergence</u>	<u>Type</u>
<u>Leptophlebia</u> <u>cupida</u>	July	Aug	autumn winter spring	June-July	univoltine
<u>Tricorythodes</u> <u>minutus</u>	Aug- June	June	July	July-Aug	univoltine
<u>Caenis</u> <u>simulans</u>	Aug- Sept	Sept-Nov	autumn spring	June-July	univoltine
<u>Baetis</u> sp. summer generation	May- June	June	summer	Aug-Sept	bivoltine
winter generation	Sept	Nov	winter	May-June	
<u>Taeniopteryx</u> <u>nivalis</u>	April- Oct	Oct- Nov	winter	April-May	univoltine
<u>Neureclipsis</u> <u>bimaculatus</u>	July	July	summer autumn spring	June-July	univoltine
<u>Hydropsyche</u> <u>recurvata</u>	Aug	Aug-Sept	summer autumn spring	July-Aug	univoltine
<u>Cheumatopsyche</u> sp.	Aug	Sept	autumn spring summer	Aug	univoltine

Production

The La Biche and Wandering Rivers, unlike most lotic systems, do not exhibit a continuous flowing environment from headwaters to confluence. Instead, these rivers, like many rivers of the poorly drained regions of northern Canada, are interrupted by lakes of varying size. It is obvious that Lyle Lake markedly affects the fauna of Wandering River. Square-foot bottom samples taken at W-I in summer and autumn indicated a large standing crop in terms of both numbers and biomass; but winter stagnation in the lake reduced the standing crop drastically during the last three to four months of winter. There was no winter stagnation in Lac la Biche and hence no reduction of winter bottom fauna in the La Biche River downstream from this lake. Although from summer samples Wandering River appears to have a greater production than La Biche River, the elimination in winter of bottom invertebrates in the former reduces considerably its annual production. To determine the production of a stream such as Wandering River, therefore, it is imperative that samples be taken during the entire year, as otherwise the results will be invalid or misleading.

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Appendix I: Temperature of La Biche River, 1965 to 1967.

<u>Station</u>	<u>Date</u>	<u>Time</u>	<u>Temperature (° C)</u>
L-I	1965 21 May	1500	9.5
	7 June	-	13.0
	8 June	-	12.6
	7 July	1030	20
	9 July	1130	19.9
	23 July	1030	20.5
	8 August	1200	22.5
	1966 4 June	1130	13.0
	23 June	1115	16.5
	22 July	1200	19.0
	24 August	1000	16.0
L-II	1965 9 June	1330	11.5
	7 July	1200	20.5
	8 August	1300	23.0
	24 August	1400	18.5
	1966 27 May	1300	13.0
	23 June	1600	19.0
	20 July	1200	19.0
	24 August	1400	17.0
	15 September	1400	14.5
	16 October	1100	5.0
	19 November	0900	0
	20 December	0900	- 1

Appendix I (continued)

<u>Station</u>	<u>Date</u>	<u>Time</u>	<u>Temperature (°C)</u>
L-II	1967 27 January	0930	1
	26 February	1115	0
	27 March	1200	0.5
	30 April	1000	3.75
	25 May	1000	13.0
L-III	1965 9 June	1430	17.5
	9 June	1600	19.0
	11 June	-	17.9
	7 July	1400	21.0
	23 July	1200	21.0
	8 August	1400	22.5
	24 August	1500	19.0
	1966 27 May	1100	13.5
	24 June	1230	18.0
	20 July	1030	19.0
	17 August	1030	13.0
	15 September	1500	14.5

Appendix II: Temperature of Wandering River, 1965 to 1967.

<u>Station</u>	<u>Date</u>	<u>Time</u>	<u>Temperature (°C)</u>
W-I	1965 13 June	1430	16.4
	9 July	1500	20.3
	4 August	1100	23.0
	18 August	1315	19.0
	8 September	1045	11.4
	1966 26 May	1500	11.5
	24 June	1100	19.0
	19 July	1500	20.0
	20 July	0900	14.0
	3 August	-	17.0
	17 August	1200	13.0
	15 September	1530	14.5
	16 October	1400	4.0
	19 November	1100	1.0
	20 December	1100	- 1.0
	1967 27 January	1115	0.5
	26 February	1230	0.5
	27 March	1300	0.0
	30 April	1200	2.0
	25 May	0900	15.0
W-II	1966 18 May	1520	9.5
	29 May	1430	11.0
	7 June	1330	8.0
	24 June	1030	15.0
	19 July	1500	19.0

Appendix III: Results of water sample analyses at W-I from June 1966 to May 1967.

	June 24	July 20	Aug 17	Sept 15	Oct 16	Nov 19	Dec 20	Jan 27	Feb 26	Mar 27	Apr 30	May 25
Total Alkalinity (ppm)	45	60	60	70	60	80	120	140	180	215	160	25
Chloride (ppm)	.2	trace	.5	.5	.8	.5	.5	.5	-	-	-	-
Hardness (ppm)	32	40	40	-	-	-	-	-	-	-	160	40
Total Phosphate (ppm)	.4	.3	.5	.4	.4	.5	.4	.4	.4	.4	.5	.4
pH	7.1	7.7	6.8	7.3	7.3	7.2	7.7	6.9	7.2	6.7	6.5	7.2
Silica (ppm)	3.1	2.3	5.6	1.6	3	1.2	1.1	1.3	2.6	1.3	2.4	1.4
Sulphate (ppm)	5	5	8	7	14	10	12	20	22	22	22	11
Turbidity (Jackson units)	35	35	40	30	90	40	40	45	80	65	60	40

Appendix IV: Results of water sample analyses at L-II from July 1966 to May 1967.

	July 20	Aug 21	Sept 15	Oct 16	Nov 19	Dec 20	Jan 28	Feb 26	Mar 27	Apr 30	May 25
Total Alkalinity (ppm)	100	120	150	130	140	150	160	150	160	100	90
Chloride (ppm)	2.5	.5	.5	.5	.5	.5	.5	-	-	-	-
Hardness (ppm)	70	70	-	-	-	-	-	-	-	110	105
Total Phosphate (ppm)	.5	.3	.3	.5	.5	.5	.5	.4	.4	.7	.4
pH	8.3	8.6	7.4	8.5	8.2	8.4	7.8	8.3	8.6	7.2	8.2
Silica (ppm)	3.5	1.7	.6	.2	.6	.5	.5	.5	.6	2.5	.9
Sulphate (ppm)	20	12	11	3	9	12	12	9	9	15	10
Turbidity (Jackson units)	35	10	25	5	2	18	7	5	10	20	10

Appendix V: Numbers of larvae present at W-I from June 1966 to May 1967.

Taxa	June 24	July 19	Aug 17	Sept 15	Oct 16	Nov 19	Dec 19	Jan 28	Feb 26	Mar 27	Apr 30	May 25
<u>Tricorythodes minutus</u>	0	45	2	0	0	0	0	0	0	0	0	0
<u>Caenis simulans</u>	132	23	0	2	17	18	3	0	1	2	0	0
<u>Baetis</u> sp.	204	34	77	1	2	7	9	7	0	0	0	0
<u>Neureclipsis bimaculatus</u>	34	64	71	22	37	10	4	1	2	1	7	12
<u>Hydropsyche recurvata</u>	6	259	165	167	259	371	732	265	187	173	0	0
<u>Cheumatopsyche</u> sp.	0	111	42	25	126	104	159	71	63	18	0	0

Appendix VI: Numbers of larvae present at L-II from May 1966 to May 1967.

Taxa	May 27	June 23	July 20	Aug 24	Sept 15	Oct 16	Nov 19	Dec 19	Jan 28	Feb 26	Mar 27	Apr 30	May 25
<u>Leptophlebia</u> <u>cupida</u>	4	0	0	1	2	5	9	3	7	1	1	14	0
<u>Tricorythodes</u> <u>minutus</u>	0	1	16	9	0	0	0	0	0	0	0	0	0
<u>Caenis simulans</u>	2	8	0	0	0	0	2	0	2	0	0	0	1
<u>Baetis</u> sp.	12	233	201	251	93	18	20	1	29	2	7	79	65
<u>Neureclipsis</u> <u>bimaculatus</u>	3	0	0	0	0	0	0	1	0	0	0	0	0
<u>Hydropsyche</u> <u>recurvata</u>	14	1	1	0	1	11	25	0	15	1	1	10	3
<u>Cheumatopsyche</u> sp.	7	0	0	3	2	22	15	5	14	5	13	34	17
<u>Taeniopteryx</u> <u>nivalis</u>	0	0	0	0	0	0	13	4	4	0	0	0	0

Appendix VII: Percent composition by number at L-II, June 1966 to May 1967. Only those organisms present in two samples or constituting more than 1 % of one sample are listed.

Taxa	June 23	July 20	Aug 24	Sept 15	Oct 16	Nov 19	Dec 19	Jan 28	Feb 26	Mar 27	Apr 30	May 25
<u>Baetis</u> sp.	16.0	40.2	36.5	48.6	4.9	2.7	0.7	6.8	0.7	8.0	6.4	11.2
<u>Caenis simulans</u>	0.6	0	0	0	0	0.3	0	0.5	0	0	0	0.2
<u>Leptophlebia cupida</u>	0	0	0.1	0.3	1.4	1.2	2.0	1.6	0.4	1.1	1.4	0
<u>Tricorythodes minutus</u>	0.1	3.2	0.9	0	0	0	0	0	0	0	0	0
<u>Heptagenia</u> sp.	0.1	0	0	0	0.3	0.3	0.7	0.9	0	1.1	0.2	2.0
<u>Taeniopteryx nivalis</u>	0	0	0	0	0	2.0	2.7	0.9	0	0	0	0
<u>Hydropsyche recurvata</u>	0.1	0.2	0	0.1	3.0	3.3	0	3.5	0.4	1.1	1.0	0.5
<u>Cheumatopsyche</u> sp.	0	0	0.4	0.3	6.0	2.0	3.4	3.3	1.8	14.8	2.4	2.8
<u>Phryganea</u> sp.	0	0	0	0.1	0	0	0	0	0.4	0	0	0
<u>Simulium</u> spp.	5.3	4.6	0.6	4.2	22.1	44.0	23.1	23.0	4.8	45.5	31.6	61.1
Tendipedidae	0.2	0	0	0	3.2	13.6	27.2	13.6	36.6	6.8	16.0	2.7
Corixidae	0	0	0.1	1.7	8.6	0.1	0	0	0	0	0.9	0
Elmidae	0	0	0	0	0	0	0	0	0	0	0.1	0.5
<u>Gammarus lacustris</u>	6.8	50.0	33.1	13.7	18.3	5.6	0	1.6	3.3	0	4.8	2.0
<u>Hyalella azteca</u>	68.5	1.8	20.5	26.6	22.6	17.6	25.9	19.7	25.6	17.1	25.1	7.7
<u>Dugesia tigrina</u>	0.8	0	6.4	2.8	4.9	6.5	4.8	9.1	15.4	1.1	2.3	1.3
Hirudinea	0.1	0	0.1	0	0	0.1	0	0.5	0	0	0.8	0.8
Oligochaeta	0.1	0	0	0.1	0.5	0.4	0.7	0.5	1.1	1.1	0.5	1.2
Nematoda	0	0	0	0	0.3	1.6	3.4	13.4	5.9	2.3	2.9	4.5
<u>Pisidium</u> sp.	0.1	0	0	0.4	2.7	0	2.0	0.9	2.9	0	1.2	1.3
<u>Sphaerium</u> sp.	0	0	0	0	0.3	0	0	0	0.4	0	0.5	0
Gastropoda	0	0	0.7	1.1	0.8	0.5	2.7	0	0.4	0	0.3	0

Appendix VIII: Percent composition by number at W-I, June 1966 to May 1967. Only those organisms present in two samples or constituting more than 1 % of one sample are listed.

Taxa	June 24	July 19	Aug 17	Sept 15	Oct 16	Nov 19	Dec 19	Jan 28	Feb 26	Mar 27	Apr 30	May 25
<u>Baetis</u> sp.	28.2	4.4	5.3	0.4	0.4	1.1	0.8	1.7	0	0	0	0
<u>Caenis simulans</u>	15.8	0	0	0.7	3.0	2.8	0.3	0	0.3	0.7	0	0
<u>Leptophlebia cupida</u>	0	0	0	0	2.8	0.5	0.4	0	0	0	1.1	0
<u>Tricorythodes minutus</u>	0	5.8	0.1	0	0	0	0	0	0	0	0	0
<u>Heptagenia</u> sp.	0.2	0.6	0	0	0	0.3	0.1	0	0	0	0	0
<u>Hydropsyche recurvata</u>	0	33.1	68.0	62.1	45.7	57.1	68.2	65.6	55.5	64.1	0	0
<u>Cheumatopsyche</u> sp.	0	14.2	17.5	9.3	22.1	16.1	14.8	17.6	18.7	6.7	0	0
<u>Neureclipsis bimaculatus</u>	4.1	8.2	4.9	8.2	6.5	1.5	0.4	0.2	0.6	0.4	7.6	13.0
<u>Athripsodes resurgens</u>	0.2	0.1	0.2	1.9	0.4	0	0.1	0	0	0	0	0
<u>Psychomyia</u> sp.	0	0	0.3	0	0	0	0.4	0	0	3.0	3.3	1.1
<u>Simulium</u> spp.	10.5	14.0	0	1.5	0	0.3	1.7	3.2	0.3	0	0	0
Tendipedidae	18.3	0	1.8	5.2	7.8	11.5	11.2	5.4	15.1	17.0	28.3	3.2
Corixidae	0.1	0	0.1	0	0	0	0.1	0	0	0	0	0
Elmidae	0.7	0.4	1.0	2.2	0.5	0.5	0.8	0.7	0.6	0.7	6.5	0
<u>Gammarus lacustris</u>	4.4	5.0	0.5	0.7	9.3	7.0	0	2.5	2.4	4.1	29.4	61.3
<u>Hyaella azteca</u>	10.4	3.1	0	0.4	0.7	0	0	0	0	0.4	0	9.7
Hirudinea	0.4	0.1	0	0.7	0	0	0.1	0	0.3	1.9	0	1.1
Oligochaeta	0.4	1.3	0	0.4	0	0	0	0.2	3.3	0.4	14.1	10.8
Nematoda	0.2	0	0	0	0	0	0	0.7	0	0	0	0
<u>Pisidium</u> sp.	4.2	0	0.1	2.6	0.7	0.9	0.4	0.5	0.6	0.7	9.8	0
<u>Sphaerium</u> sp.	0	1.8	0	0	0.2	0	0.2	0.2	0	0	0	0

Appendix IX: Organisms found in the La Biche and Wandering Rivers during the study period. (L) La Biche River; (W) Wandering River; (B) both rivers.

Cnidaria-Hydrozoa

Hydra canadensis (L)

Platyhelminthes-Turbellaria

Dugesia tigrina (L)

Annelida-Oligochaeta

Lumbriculus sp. (B)

Limnodrilus sp. (B)

L. hoffmeisteri (W)

L. claparedeanus (W)

Annelida-Hirudinea

Glossiphonia complanata (B)

Nephalopsis obscura (B)

Erpobdella punctata (B)

Mollusca-Gastropoda

Gyraulus crista (W)

Physa heterostropha (B)

Limnea stagnalis (B)

Valvata tricarinata (B)

V. bicarinata (W)

Heliosoma anceps (B)

Mollusca-Lamellibranchiata

Lampsilis sp. (L)

Sphaerium sp. (B)

Pisidium sp. (B)

Musculium sp. (L)

Appendix IX (continued)

Arthropoda-Crustacea-Amphipoda

Hyalella azteca (B)

Gammarus lacustris (B)

Arthropoda-Insecta-Hemiptera-Gerridae

Gerris sp. (B)

Arthropoda-Insecta-Hemiptera-Corixidae

Callicorixa audeni (B)

Sigara fallenoidea (L)

S. solensis (L)

S. washingtonensis (B)

S. bicoloripennis (L)

S. decoratella (B)

S. conocephala (B)

Callicorixa alaskensis (L)

Cymatia americana (B)

Arctocorisa utilis (W)

A. convexa (L)

Cenocorixa sp. (L)

Dasycorixa johanseni (W)

Trichocorixa verticalis (W)

T. naias (W)

Hesperocorixa atopodonata (W)

Arthropoda-Insecta-Ephemeroptera

Hexagenia limbata (B)

Baetis sp. (B)

Tricorythodes minutus (B)

Appendix IX (continued)

Caenis simulans (B)

Heptagenia sp. (B)

Leptophlebia cupida (B)

Callibaetis sp. (B)

Siphonurus sp. (B)

Siphloplecton basale (W)

Ephemerella subgenus Serratella (W)

Arthropoda-Insecta-Plecoptera

Arcynopteryx parallela (W)

Taeniopteryx nivalis (L)

Isogenus sp. (B)

Arthropoda-Insecta-Trichoptera

Limnephilus sp. (B)

Hydropsyche recurvata (B)

Cheumatopsyche sp. (B)

Neureclipsis bimaculatus (B)

Athripsodes resurgens (B)

Agraylea sp. (L)

Phryganea sp. (B)

Psychomyia sp. (B)

Lepidostoma sp. (L)

Arctopsyche sp. (W)

Arthropoda-Insecta-Lepidoptera

Schenobius sp. (B)

Appendix IX (continued)

Arthropoda-Insecta-Coleoptera

Elsianus sp. (B)

Gyrinus sp. (B)

Agabus sp. (L)

Oreodytes sp. (L)

Donacia sp. (L)

Arthropoda-Insecta-Odonata

Ischnura sp. (L)

Coenagrion sp. (L)

Aeshna sp. (B)

Arthropoda-Insecta-Diptera-Tabanidae

Chrysops sp. (B)

Arthropoda-Insecta-Diptera-Simuliidae

Simulium venustum (B)

Simulium vittatum (B)

Arthropoda-Insecta-Deptera-Culicidae

Chaoborus sp. (W)

Appendix X: Plankters of the La Biche and Wandering Rivers.
(L) La Biche River; (W) Wandering River; (B) both
rivers.

Myxophyceae

Anabaena sp. (B)

Gleotrichia echinulata Richter (W)

Bacillariophyceae

Stephanodiscus sp. (B)

Fragilaria spp. (B)

Gyrosigma sp. (B)

Cocconeis sp. (B)

Navicula sp. (L)

Cymbella sp. (B)

Surirella sp. (W)

Asterionella sp. (B)

Rotifera

Keratella canadensis Berzins (B)

K. cochlearis (Gosse) (B)

Cladocera

Daphnia schødleri Sars (W)

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